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SOME OF THE FORGOTTEN MEN IN THE FIELD OF THORACIC SURGERY

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AS an introduction to the talk I want to give this afternoon, I shall read to you from the Constitution of this Association. Article II deals with the object of the Association. It says: "The object of this Association shall be to encourage and stimulate investigation and study that will increase the knowledge of intrathoracic physiology, pathology and therapy, to correlate such knowledge and disseminate it." So, you see, this Association was not established to honor men who had already made contributions to thoracic surgery, but to encourage work in this field. Therefore, we should be interested in those men who have made noteworthy contributions, even if their work has not brought them fame. In speaking of them, however, I am not unmindful of the many men in this audience today who have made great contributions, and have also received just praise for it. I thoroughly agree with this acclamation and am sure that there is no one here who admires them more than I. To list them is unnecessary, for you all know them. I have no desire to detract in any way from this acclaim. I only want to add to this group the names of some others who, I think, should be among them.

The first subject I want to talk about is one that is familiar to everyone. I refer to decortication of the lung. This procedure was first publicly described by G. R. Fowler,[15] in 1893. There is some evidence that Carl Beck[5] did this operation at an earlier time, but he did not publish a report of his work which had been presented before the German Surgical Society in New York. During the two years following Fowler's paper, Délorme[11] in France, and Lambotte[19] in Belgium, wrote about this procedure and reported their experience with it. Their operations differed from the modern one only in

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regard to resection of the chest wall and in the method of drainage. They resected large segments of many ribs and packed the wound open with gauze after completing the decortication. Although the operation was widely discussed, it was not widely used, and one can well understand why that was true, as blood transfusion was far in the future. Between that time and 1918, the procedure was only occasionally discussed in the literature.

In the latter part of 1918, when the First World War was drawing to a close, there was the terrible influenza epidemic and a tremendous number of cases of empyema developed among the survivors. A great many of these occurred in the soldiers, and at Walter Reed Hospital in Washington, Col. William Keller and Dr. Carl Eggers, had charge of them. They published many articles on the subject, and Dr. Eggers[14] published the results of his use of decortication for chronic empyema. He performed the operation on 99 soldiers and only one of them died—no antibiotics, and no blood transfusions. Sixty-seven of the men had excellent results with re-expansion of their lungs. The others needed further plastic operations. The operation which he did then, as published in the *Annals of Surgery* for March, 1923, was very similar to that done today and I am going to show you some lantern slides to illustrate the various steps. The only point of difference had to do with drainage. He used an open tube, although Dr. Mann,[24] Professor of Surgery at the University of Minnesota, as far back as 1907 emphasized the importance of closed drainage in such circumstances. After this important report, Dr. Eggers did not publish any further ones, presumably, because he felt that nothing further needed to be said. In spite of his excellent results, the operation was not accepted. Hedblom[34] reported on his experiences at the Mayo Clinic with 150 cases of chronic empyema treated between 1917 and 1920 in which he did decortication in 30. In 15, the results were excellent. He felt that the operation had a place, but a limited one. Practically all of the other leading thoracic surgeons in this country were opposed to this procedure. They felt it was too formidable an operation for rather limited results. Dr. Bigger was the only other man I knew, besides myself, who felt the operation should be used. I tried it successfully, in 1929, for a chronic empyema and again, in 1940, for a chronic hemothorax. In the autumn of 1943, I gave a talk on the subject before the county medical society in Memphis and reported on 3 cases which had been treated at Kennedy General Hospital. As I had nothing new to offer I never published anything on the subject. Soon after this, in North Africa and Italy, decortication was found to be very effective in treating chronic hemothorax in the wounded soldiers, and the reports of Samson, Burford, Brewer and Burbank, and others, brought the procedure to the eyes of all. Soon it was found that decortication was just as useful in cases of empyema, and since then it has been applied to all types of cases in which the lung has been entrapped by a membrane. In none of the numerous papers written on the subject since 1943 have I seen a single reference to the work of Dr. Eggers. Surely his name should stand together with those of Fowler[15] and Délorme.[11]

Now, I want to move over into a very different field of activity. The surgery of mitral stenosis has changed from a spectacular operation, in 1948, to a procedure that is successfully used throughout the entire world. The recently trained thoracic surgeon today, looks upon mitral commissurotomy as we older men looked upon appendectomy. And yet, the development of this operation took a great many years, and passed through stages when the leaders in the field thought that further work on the subject was futile with the means then at hand. However, with no new weapons, the operation became established. Back in 1898, an English physician by the name of Samways[30] said in an article on the peristaltic movements of the auricle that notching the stenotic mitral valve might be of value in treating mitral stenosis. That is all he said, and did not write further about this idea. However, in 1902, Sir Lauder Brunton[7] published an article in the *Lancet*, on February 8, in which he very decidedly advocated the resection of a segment of the stenotic mitral valve. Let me read you what he said: "Mitral stenosis is not only one of the most distressing forms of cardiac disease, but in its severe form it resists all treatment by medicine. On looking at the contracted mitral orifice in a severe case of this disease, one is impressed by the hopelessness of ever finding a remedy which will enable the auricle to drive the blood in sufficient stream through the small orifice, and the wish unconsciously arises that one could divide the constriction as easily during life as one can after death. . . . But no one would be justified in attempting such a dangerous operation as dividing a mitral stenosis in a fellow creature without having first tested its practicability and perfected its technique by previous trials on animals." He then went on to say, that he had obtained the necessary licenses to do the work, but because of pressure of other duties had only been able to do the operation on cats, dead animals, and diseased hearts obtained at post-mortem. Then he said, "It may be some months longer before I can get anything more done and I therefore think that it may be worthwhile to write this preliminary note, especially as after all, if the operation is to be done in man, it will be surgeons who will do it and they must, of course, make their own preliminary experiments, however fully the operation may be described by others, and each must find out for himself the method which he will employ in each particular case." In spite of the caution expressed in this article, and the statement that surgeons would have to work out the technique, he was severely attacked in the *Lancet* by a leading article the week after his article appeared. He was attacked for suggesting such a radical procedure without first having perfected the operation himself. And yet, everyone knew that he was not a surgeon but was one of the most distinguished cardiologists in England, and even a Fellow of the Royal Society. The only surgeon who entered into the discussion was Sir Arbuthnot Lane,[22] who said that he considered the operation feasible, and "under certain circumstances justifiable." He said nothing else, and no other surgeon had anything to say. This reticence on the part of the surgeons is of great interest when one looks back at the state of surgery at that time. In looking

through the *Lancet,* the *British Medical Journal,* and *Annals of Surgery* for that year I was tremendously interested in reading of the great amount of surgery being done at that time. Abdominal surgery was well advanced and had Sir Lauder proposed some new abdominal procedure it would have been carried out at once. It might be of interest to cite here a few of the surgical events chronicled in these journals. But first it might be well to point out that England was then engaged in the Boer War which did not come to an end until June 1, 1902. Marmaduke Sheild,[31] of London, reported the results of operation in 60 cases of malignant tumors of the breast. He pointed out the importance of the radical operation, and said that Halsted was to be congratulated because he had revived the operation introduced by Moore of the Middlesex Hospital in London, in 1867. He concluded his article by saying, "operate early, operate extensively." There was a paper on hysterectomy for cancer of the uterus with the statement that the vaginal route was the better one in most cases. A. W. Mayo Robson[26] reported on 200 operations for obstructive jaundice with a mortality of 13.6 per cent. Most deaths were due to hemorrhage. This was five years before Crile started doing transfusions, and eight years before typing of blood really became established, and transfusions could be safely used. One of Europe's greatest surgeons, Doyen[12] of France, reported on the isolation of a diplococcus which he considered to be the etiologic agent in cancer. He said that he had been able to isolate it in every one of his cancer cases. He had prepared a vaccine and had used it in all patients except those with the rapidly growing tumors. In the same year, April, 1902, at the German Surgical Congress[13] he had shown moving pictures of trephining, resection of the knee joint, and finally his famous operation for separation of the xiphopagus Hindu girls. There was a report in the *Lancet* in that year of the meeting of the Society of Anesthetists of Great Britain, on Dec. 6, 1901. At this meeting the chief subject for discussion was "Is Chloroform More Dangerous than Ether? Consideration of Respiratory Troubles Following Operations During Twelve Months at a Large General Hospital." In spite of the fact that there were a large number of doctor anesthetists in England at that time, and much interest was taken in it, there was no satisfactory anesthesia for chest surgery. Although intratracheal anesthesia had been introduced by Matas,[25] in 1901, it had not been used to any extent except in experimental work, and without it it was impossible to operate in the open chest. Only by first creating adhesions in the chest was it safe to open the chest for an operation as the uninvolved part of the lung had to adhere to the chest wall so as not to collapse when the chest was opened. Rehn, in 1896, had successfully sutured a stab wound of the heart and others had been done since then. The management of stab wounds of the chest had been well worked out, and the dangers of pneumothorax were understood. However, no surgeon of that day would lightly consider operating in the open chest and no one would dare operate on the heart except to suture a wound in it. Shortly before Rehn's successful case, the great

Billroth had declared that any surgeon who dared operate on the heart would lose the respect of his fellow surgeons. So, it is not surprising that no surgeon ventured to follow Sir Lauder Brunton's suggestion.

Although no surgeons in England became interested in the possibility of surgery for heart disease, a great deal of experimental work was done in Germany, France, and in this country after this. In 1922, Graham and Allen[2] began work on surgery for mitral stenosis, and in dogs, succeeded in biting out pieces of the mitral valve with an instrument with which they could see the tissue which they cut. Allen[3] succeeded in getting an answer to the question as to what happened to the valve after it was cut. Many thought that a valve that was divided, or cut, would heal and restore the stenosis. Allen told me recently, that he talked the matter over with Dr. Caulk, the noted urologist in St. Louis. Allen compared the stenotic mitral valve to a urethral stricture. The great difference being that urine passed infrequently through the urethra, while blood poured continuously through the mitral valve. Believing that the valve would not resume its structure, he tried the problem experimentally. He cut the valves of a series of dogs, and eleven months later studied them. The cut edges had become epithelized, and there was no tendency to recurrence of the stenosis. With this knowledge, and having perfected their technique on dogs, Graham and Allen searched in vain for a patient. They planned to approach the valve by way of the auricular appendage. None of their colleagues at Washington University were interested. Finally, a doctor from out in the country sent them a patient. She was so sick that they planned to operate on her in stages. Even so, at the third stage she died, just as they were getting ready to introduce the cardioscope. After Graham and Allen had done many of their experiments, Cutler and Beck,[10] in Boston, began work on the problem, and finally in April, 1923,[9] they succeeded in dividing the stenotic mitral valve of a young girl by the ventricular approach. She recovered, and her case was promptly reported. News of this great event spread throughout the world, and it was generally thought that a new era of thoracic surgery had dawned. It was the intention of Cutler and Beck to resect a segment of the mitral valve as they thought that was necessary to correct the stenosis. In their first case, however, they had decided that they had better be content with simple division of the valve. In their subsequent cases they did carry out resection, but all of the patients died. Two years after Cutler and Beck's successful case, Henry Souttar,[32] in London, operated on a young woman who was supposed to have mitral stenosis. He approached the valve as Graham and Allen had done, by way of the auricular appendage, and found on finger exploration, that there was no real stenosis, but some regurgitation. He inserted his finger through the valve and explored both the ventricle and auricle, and wrote that he thought this was the proper attack on mitral stenosis. His patient recovered and lived for some years. At this time, in England, the teachings of Sir James Mackenzie were authoritative and everyone followed them religiously. He had died at 72, some six months before Souttar did his operation, but his

opinions about the heart were universally followed. Therefore, Souttar was unable to get any more patients on whom to operate, as Mackenzie had held that the important feature of mitral stenosis was the damaged myocardium, and that the valve deformity was of secondary importance. Thus, it was useless to operate on the valve. In this country, Dr. Samuel Levine,[23] in Boston, did not agree with Sir James, and he referred a number of patients to Cutler for operation, even though all died after the first one. The fact that Souttar's patient did not have true stenosis, and therefore was unaffected by the operation, accounted in some degree for the lack of attention attracted by his article. During the time that Cutler and Beck were operating on their patients with mitral stenosis, no one had been able to produce mitral stenosis in the experimental animal. However, between 1929 and 1932, John Powers,[29] working in the same laboratory at Harvard where Cutler and Beck had done their work, found that he could produce stenosis by cauterizing the mitral valve by means of bipolar diathermy, and then infecting the dogs with *Streptococcus viridans.* He then studied the effect of resecting portions of the valve, and found that, in every instance, the dog died from the regurgitation produced.

In 1946, as you all know, Bailey[4] was operating on a patient with mitral stenosis, and was prepared to resect a segment of the valve with a cardiovalvulotome. After entering the auricular appendage, he discovered that he would be unable to get his instrument through the valve in order to do the resection. His medical associates told him that if he didn't relieve the stenosis in some way the patient would die on the table. Suddenly, he remembered Souttar's article, and pushed his finger through the valve, splitting the commissures. Although the patient died a day later, the autopsy revealed the fact that the stenosis had been corrected without the establishment of regurgitation. He knew then that Souttar's operation was the correct one, but he had to wait two more years before he had another chance to do the operation. Then, in June of 1948, he operated on a young woman and succeeded in carrying out the operation. Six days later in Boston, Dwight Harken[18] carried out a similar procedure, but cut along the commissures with a valvulotome. Three months later in London, Russell Brock[6] carried out the Souttar operation with success. None of these men knew of the other's work at the time. And so within the period of three months, an operation that had first been carried out twenty-three years earlier came into its own. To Brunton must go the credit for fighting for the principle of surgery for mitral stenosis. To Souttar goes the credit for perfecting the operation, and to Bailey, Harken and Brock go the credit for establishing the operation as a definitive procedure.

On May 6, 1907, at the meeting of the Philadelphia Academy of Surgery, Dr. John Munro[28] of Boston, read a paper entitled, "Ligation of the Ductus Arteriosus." So important were his remarks at that time that I shall quote from his address. He started by saying, "That I may be allowed to bring this suggestion for a new operation before your Society, I ask on the basis that it

has not been hastily conceived. On the contrary long ago I demonstrated its technical possibility on the cadavers of newborn children, and felt that it was justifiable on the living. At various times I have tried to inspire the pediatric specialist with my views, but in vain. Now, in view of the recent advances in cardiac surgery, for much of which we are indebted to the surgeons of this city, I will venture to place my ideas before you, asking that you do not dismiss them hastily." He then went on to record the case of a girl baby that presented evidence of heart disease, and died after several weeks without any real cyanosis. At autopsy, the only abnormality found was "an open ductus arteriosus lying easily within reach behind the sternum. The simplicity of the remedy was so striking that I at once made further dissections, and satisfied myself that it would be possible to ligate the duct provided a diagnosis could be made beforehand. In regard to making a diagnosis, however, my pediatric advisers were not reassuring." He then spoke of studies made on the ductus, and the effort to recognize distinctive heart sounds. As the ductus is normally open during the first few days of life, it was thought that it would be possible to establish the auscultatory signs that were typical, from examination of many newborns. This did not prove to be true, although Townsend examined 100 newborn babies during the first three days of life. He then discussed the question of the etiology of delay in closure of the ductus, and said that nothing was known about this.

His description of the characteristic findings in a case of patent ductus is still true in most respects. First, he said that there was no cyanosis, except occasionally in late life. "Cardiac dullness is increased laterally, and there may be projection and pulsation of the dullness leftwards, in the upper costal spaces. This projection is visible by x-rays. A loud systolic whir conducted into the cervical vessels may be heard, but as a matter of fact there are no definite auscultatory signs established as yet. Of the 26 cases collected recently, half lived to puberty. Death follows from atelectasis, general oedema, pleural exudate, pneumonia, endocarditis, etc."

"Why should we consider surgical interference in cases of open ductus arteriosus? Because in spite of the fact that some cases may live to puberty, the chances of which must be small, we have the one cardiac-valvular lesion, which is, relatively speaking, superficial. Furthermore, the anomalous vessel is of good size, its ligation must be followed by instant and permanent restoration to a normal function of the lungs and arteries, and it can be reached by a short surgical route."

"The operation I would propose, as demonstrated on the cadaver, is as follows: Under ether anesthesia, which I prefer to chloroform in any case involving collapse of the lung, the sternum can be easily split along its center or a little to the right, opposite the second costal cartilage. This is easily done with a knife. The sternal halves are then retracted, ample room for working being obtained. The right pleural cavity will probably be opened but the left one will not. Judging from analogous cases in surgery, this should not be serious, but if necessary the physiologist's apparatus for main-

taining artificial respiration could be employed. I hardly believe that it would be needed. After retracting the thymus upward, the pericardium is exposed. Its reflection lies so high on the large vessels that the ductus to all intents and purposes is intrapericardial. In the upper angle the aorta will be seen on the patient's right and the pulmonary artery on the left. By following close to the aorta toward the under surface of the arch the ductus, as large as the aorta itself, will be seen as the first vessel to the left pointing upward and a little to the right. Both pulmonary branches lie too far posteriorly to be seen, and by keeping close to the aorta the main pulmonary trunk will escape injury. On pushing through the tissues by blunt dissection the ductus, theoretically, should be easily surrounded with a ligature. It is a question whether or not simply crushing it would not accomplish as much, and in case of necessity, I believe that it would be worth trying. After closing the anterior pericardial wound the sternum can be sutured or not and the skin closed."

"Would it be justifiable to subject a child to this risk without knowledge of the exact lesion? In a case with beginning atelectasis or other evidences of impending death from circulatory disturbances, with a reasonable basis for believing that the duct were open, it seems as though such an operation would be justifiable. I doubt if it would materially hasten a fatal issue in case the diagnosis were not confirmed."

Why was it then that this operation was not attempted? In spite of Munro's remarks about the control of pneumothorax by the physiologist's apparatus for maintaining artificial respiration, this was rarely used in the operating room, and apparently was not thought to be of practical value. At that time, surgeons were repairing stab wounds of the heart, draining lung abscess and empyema, and resecting chest-wall tumors, but they were not operating in the open chest. It was considered safe to operate on a lung, or in the chest, only if the lung were firmly adherent to the chest wall. So that it was not feasible to undertake an elective operation in the open chest. Furthermore, blood transfusion, although successfully done by Crile[8] in 7 cases, by artery vein anastomosis and unmatched blood, had not come into use. This was four years before Moss[27] demonstrated the four types of blood, and blood typing was done. It is true that Landsteiner[20, 21] had demonstrated types of blood in 1900 and 1901, but Crile even went so far as to say that he was convinced that it was perfectly all right to transfuse blood from any member of a species to any other member. Why he had no reactions in his 7 cases is not known. So, blood transfusion was not available at that time. Who today would undertake to ligate a patent ductus without having blood available for possible use?

Thirty years after John Munro had suggested ligation of the patent ductus it was finally attempted by John Strieder,[33] in Boston. Although Munro had described the operative approach to the problem he had been unable to convince any pediatrician that the operation was feasible, and so never had a chance to do the operation himself. Maude Abbott,[1] the great

authority on congenital heart disease, in the last article she published (the article appeared in *Nelson's Loose Leaf Medicine* for 1942, but she had died in 1940) said that ligation of the ductus arteriosus had been suggested by Munro, but so far as she knew no one had attempted it. She felt that this was fortunate, as she believed that ligation of the ductus would invariably lead to production of an endarteritis, and the end condition would be worse than the original one. She did say, however, that if an obliterated ductus caused pressure on the trachea or esophagus it could safely be divided with benefit to the patient. Dr. Ashton Graybiel,[16] the cardiologist at the Massachusetts Memorial Hospital, felt that ligation of the ductus was a rational procedure, and discussed the subject with John Strieder, and with Dr. John Munro's son, Donald, a neurosurgeon. At that time it was not known whether or not Dr. Munro had attempted the operation. A search of his papers, and of the literature, failed to reveal any evidence of this. John Strieder[33] then carried out dissections in the pathology laboratory on cadavers, and so was ready to attempt the operation when Dr. Reginald Fitz referred to him a girl who was desperately ill with subacute bacterial endocarditis complicating a patent ductus arteriosus. It was thought that ligation of the ductus would save her life. The operation was done on March 6, 1937, but it was found that the pulmonary artery and the aorta were in contact, and although it was possible to separate them everywhere except posteriorly it was impossible to pass a ligature around the ductus. He then made an attempt to plicate the ductus, and a series of silk sutures were placed with almost complete disappearance of the thrill. She did well for three days and the murmur could no longer be heard, but on the fourth postoperative day, she developed an acute gastric dilatation and died in spite of everything done to correct the condition. At autopsy, it was seen that the vegetations extended from the orifice of the ductus downward to the pulmonary valves. This case report was given at the Saranac Lake meeting of the American Association for Thoracic Surgery on June 1, 1937,[33] during the period for discussion of the papers by Beck on "Augmentation of the Coronary Circulation by Operation," and by Blalock on "Tuberculous Pericarditis." He continued his discussion by saying, "We are reporting this in some detail later, but I thought I might take the opportunity to present it to the Society in case anyone had thought along similar lines and would be interested in trying it as a prophylactic measure in youngsters before they already have dilatation and hypertrophy of the heart, and also because 25 per cent of these patients with congenital heart defects die of subacute bacterial endocarditis, or endarteritis." Following this presentation, no one at the meeting had any comment to make. The following year in the *American Heart Journal,* Graybiel, Strieder, and Boyer[16] reported the case in more detail. In the conclusion to the article he said that in the future, in addition to ligating the ductus, he would attempt to obliterate the adjacent portion of the pulmonary artery so as to remove all the

vegetations from direct contact with the blood stream, and in allowing the natural defense forces to kill the bacteria. He also said that the vegetations might be removed by a modified Trendelenburg operation.

In 1939, John Hubbard[17] was in charge of the Congenital Heart Clinic at the Children's Hospital in Boston. He was interested in someone's attempting to correct surgically some of these congenital defects. He got Robert Gross[17] interested in the subject and they decided that the ductus was the first to attack. They were familiar with Munro's article. Gross then worked in the surgical research laboratory at Harvard, with Cutler's backing, and then on cadavers, to perfect an approach to the ductus. He had not been present at the meeting of this Association in Saranac Lake when Strieder made his comments, had not seen his article which appeared the following year, and did not personally know him at the time. He was therefore unaware of the attempt made by Strieder to ligate the ductus. In August, 1938, he operated on a young child with an uncomplicated patent ductus and succeeded in ligating it. The child recovered and the fame of the operation spread throughout the world.

And so I have talked about some matters that are known to many of you, and have brought fresh light to bear on them. It is not that I want to destroy any reputations, rather do I wish to add to the illustrious list known to everyone, the names of some less well known but surely deserving of attention. I hope that I have succeeded in this attempt.

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OBSERVATIONS ON A CONSERVATIVE APPROACH TO NONMALIGNANT LESIONS AT THE CARDIA

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SO long as excision of the cardia is accepted as the best treatment yet available for carcinoma of this region, extirpation should be as complete as possible. The function of the cardia has already been destroyed by the growth. The aim of the surgeon, therefore, is first to eradicate the disease, and only second to repair the defect by a method which will give the least postoperative discomfort or complication. In the surgery of nonmalignant lesions, however, there must be a greater concern for the preservation or restoration of normal function.

While radical total gastrectomy for carcinoma and reconstruction by a Roux loop represents one extreme, at the other there is the reduction and fixation of a diaphragmatic hernia which restores the cardia to its natural state. Between these two, there are fields which have become much more interesting to explore.

Cardiospasm suffered too long from an overardent surgical approach before the simple myotomy of Heller became widely accepted, but this operation is now one of the most effective conservative measures at the cardia, and, for cardiospasm is used to the exclusion of all other open operations. Endoscopic dilatation by one of the many types of inflatable balloon may be considered equally conservative and yet simpler to perform but, although this still has an important place in the treatment of uncomplicated cardiospasm, it can have certain disadvantages: it is not always effective for as long a time as myotomy; it is less certain in its immediate result; and it may so stretch the hiatus and the fascial connections of the cardia that incompetence may occur. If it is performed successfully for a patient in whom cardiospasm is associated with hiatal hernia, incompetence is inevitable, and the same is true if cardiospasm is complicated by prolapse of the cardia into the abdomen. Reflux of digestive juices into the dilated and inert esophagus of cardiospasm, however it is produced, causes severe ulceration, bleeding, and perhaps stenosis, for any of which complications resection may be necessary. Laxity at the hiatus, prolapse of the cardia into the abdomen, or a true hernia can be detected and repaired during the open operation, and so the severe complication of peptic esophagitis may be avoided. These points are illustrated by the following case histories.

Case 1.—L. H., a man aged 59, complained that for one year food had lodged behind the lower end of the sternum. It often returned mixed with large quantities of mucus. There had been no loss of weight. The radiograph showed an elongated, dilated esophagus with a smooth tapering obstruction at the cardia (Fig. 1). At esophagoscopy, the mucous

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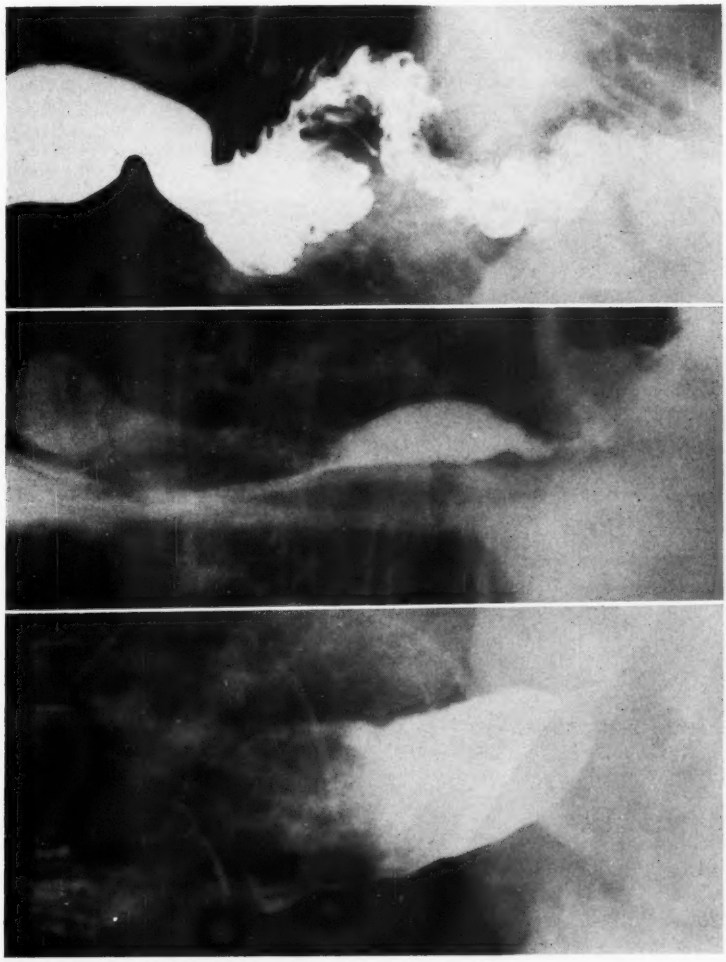


Fig. 1. Fig. 2. Fig. 3.

Fig. 1.—Case 1. Radiograph of esophagus before treatment suggesting uncomplicated cardiospasm.
Fig. 2.—Case 1. Eight months after Negus dilatation. Reduction in size of the esophagus is evident but there is rigidity and deformity of the lower end suggesting fibrosis.
Fig. 3.—Case 1. Four years after resection of stricture and esophagojejunostomy by Roux loop.

membrane was redundant but clean, and the cardia soft. The instrument was passed into the stomach without difficulty, and the cardia was dilated with the Negus hydrostatic bag. After this, the dysphagia was temporarily relieved but the patient complained of heartburn and belching. Eight months later, when dysphagia returned, radiography showed the esophagus reduced in size but with a rigid area at the lower end suggesting a fibrous stricture (Fig. 2). The presence of ulceration and stenosis was confirmed by esophagoscopy. The ulcerated section was resected and esophagojejunostomy performed (Fig. 3), when it was noted that the cardia was 5 cm. above the hiatus. Histology of the specimen showed a benign ulcer. Fibrinopurulent exudate covered a floor of granulation tissue which was infiltrated by polymorphonuclear and eosinophil leukocytes and several large foci of lymphocytes. Beneath this was a zone of more cicatrized fibrous tissue, 3 mm. deep, and scar tissue extending into both muscle coats. He regained his lost weight and has been active and without symptoms, on a normal diet and intermittent liver therapy, for five years.

Fig. 4.

Fig. 5.

Fig. 4.—Case 2. Radiograph which shows cardiospasm with prolapse of the cardia into the abdomen for 7 cm.

Fig. 5.—Case 2. Two months after myotomy and restoration of normal relations between cardia and diaphragm. The cardia was competent.

CASE 2.—L. B., a woman aged 44, complained of dysphagia for seventeen years with regurgitation of food and mucus. The radiograph showed severe cardiospasm with prolapse of the cardia into the abdomen (Fig. 4). The condition was confirmed at operation,

the dome of the diaphragm being incised to allow inspection of the cardia before any traction was applied. Seven centimeters of greatly hypertrophied esophagus lay in the abdomen. Myotomy was performed at the cardia, and the esophagus was then drawn up into the mediastinum. The fascia was sutured and the hiatus reduced to its normal size as in the treatment of hernia (Fig. 5). Relief was complete and no esophagitis occurred. After observation for four years without symptoms, the patient was discharged.

CASE 3.—E. G., a woman aged 56, complained of regurgitation and vomiting for forty-nine years, and more severe dysphagia for two years. The dysphagia was always worse when she was excited. Radiography showed a dilated esophagus with a smooth obstruction at the cardia which was typical of cardiospasm (Fig. 6). When enough barium had passed the cardia to fill the stomach, the presence of a diaphragmatic hernia became manifest (Fig. 7). No esophagitis was detected at esophagoscopy, and the cardia was soft to the passage of bougies. The patient was operated upon by Mr. G. H. Wooler who confirmed the anatomic abnormality, performed a myotomy at the cardia, and repaired the hernia.

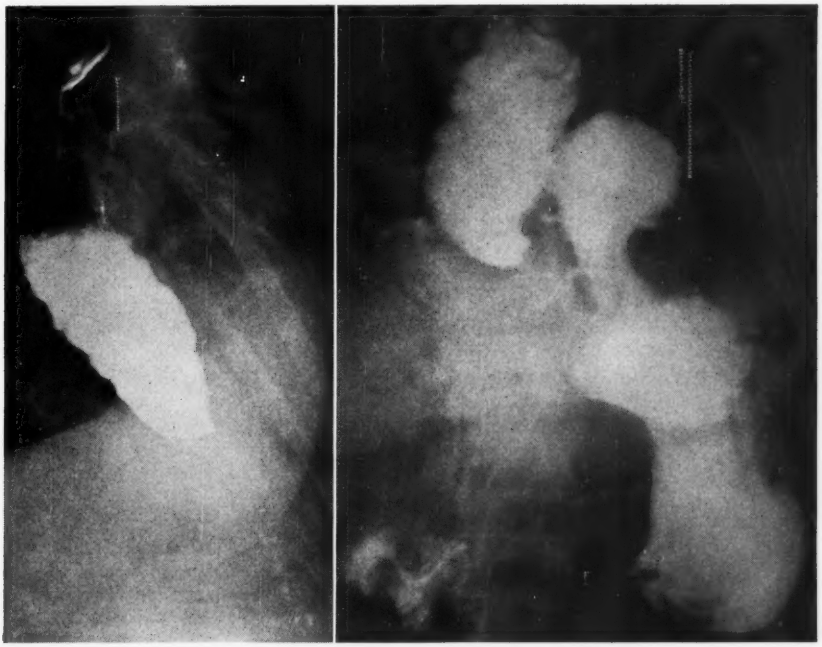


Fig. 6. Fig. 7.

Fig. 6.—Case 3. Radiograph of an apparently uncomplicated cardiospasm.
Fig. 7.—Case 3. A radiograph shows the esophagus nearly empty. Stomach filled. Abdominal compression demonstrates hiatal hernia complicating cardiospasm.

Sometimes the function of the cardia may be destroyed by faulty surgery and the question of its restitution arises. The situation is not necessarily hopeless and may be retrieved so long as deep fibrous scarring has not replaced the muscle elements, as the following example demonstrates.

CASE 4.—D. H., a woman aged 39 years, had suffered for many years from pulmonary tuberculosis for which she had had a right-sided artificial pneumothorax and thoracoplasty.

For ten years she complained of retrosternal discomfort which was exaggerated by domestic anxieties. A radiographic examination showed a very active esophagus which, perhaps mistakenly, was diagnosed and treated as cardiospasm. The surgeon who performed the operation thought to increase the effectiveness of esophageal myotomy by incising the crural fibers on the left lateral side of the hiatus. After this, discomfort was greatly increased, the cardia incompetent (Fig. 8), and the esophagus was found to be extensively inflamed and superficially ulcerated. As no fibrous stenosis had developed, an operation was done to restore the competence of the cardia. The muscle fibers of the crus were found to be widely retracted where they had been cut, and the gap was filled with omental fat. The

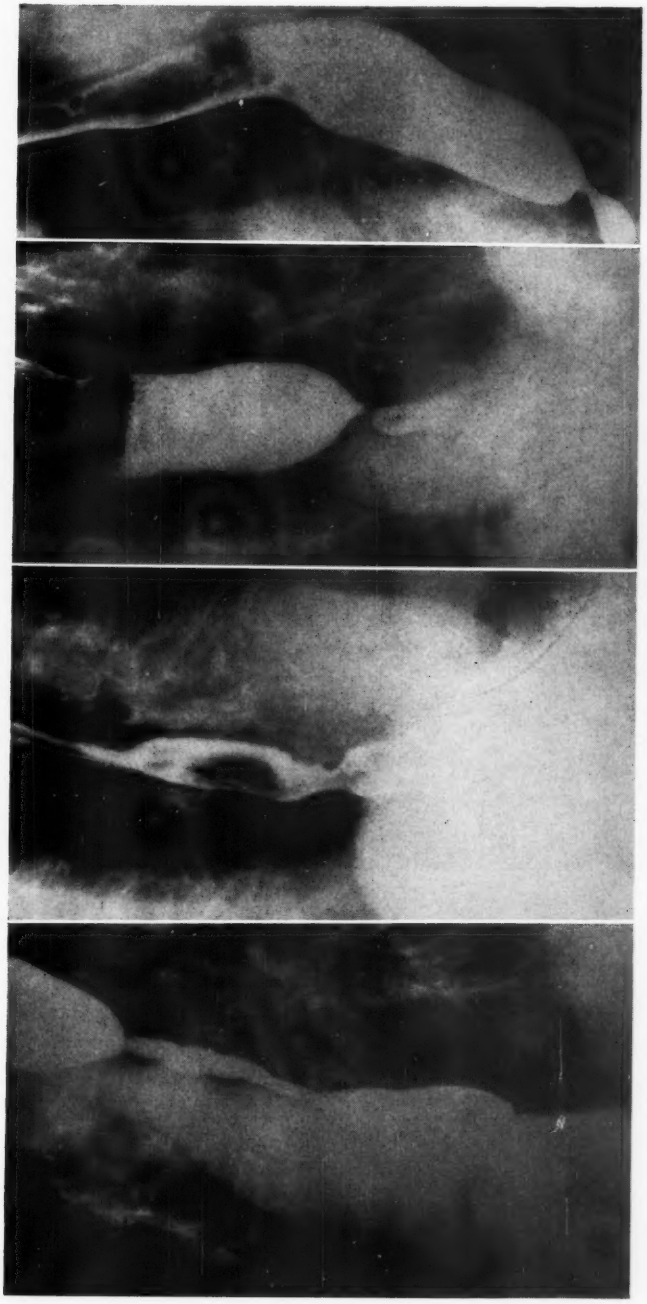
Fig. 8.

Fig. 9.

Fig. 8.—Case 4. A radiograph showing a patulous cardia after Heller myotomy and division of the crus on the left side of the hiatus. Cushing clips on cut edges of esophageal muscle.

Fig. 9.—Case 4. Restoration of normally functioning cardia by suture of muscle and fascial elements. The Cushing clips are 1.5 cm. above the cardia. The narrowing 4 cm. above this is apparent only, and caused by marked traction to the right of the mediastinum from pulmonary tuberculosis.

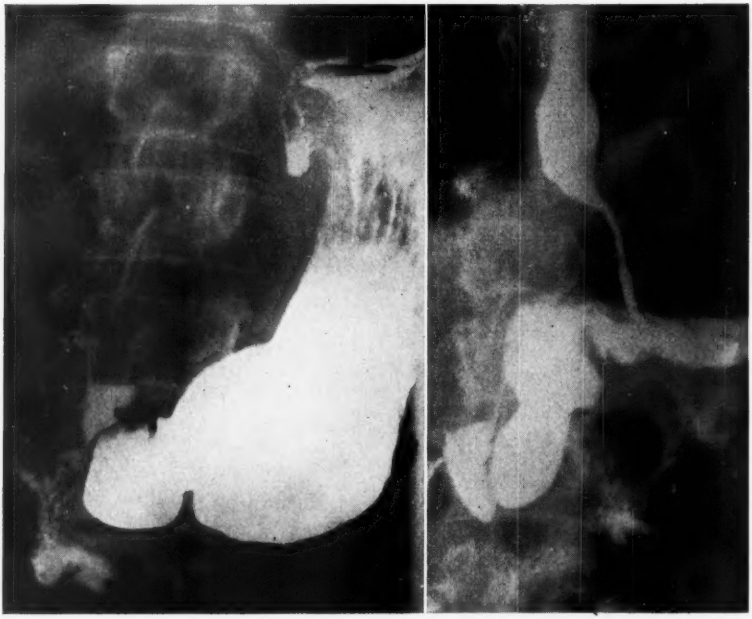
hiatus was very wide. The muscle of the esophagus also had retracted where the Heller myotomy had been performed and two Cushing clips had been applied to its cut edges. The mucous membrane was covered by a thin layer of fibrous tissue only. This tissue was excised, and the muscular coat of the esophagus was carefully freed and then approximated by fine interrupted catgut sutures. The scar tissue in the diaphragm was excised and the crural fibers sutured. The hiatus was then further reduced in size by one stitch in front of the esophagus and three behind. The dome of the diaphragm was incised and the ligaments of the cardia sutured to its under aspect by six interrupted silk sutures, as for a simple hernia. After this the esophagitis cleared up, and radiography confirmed that the cardia was competent (Fig. 9).



A. *B.* *C.* *D.*

Fig. 10.—*A*, Long, *B*, medium, *C*, short, and *D*, weblike stenoses of esophagus from esophagitis secondary to hiatal hernia.

Some of the greatest difficulties arise in the treatment of the simple stenoses arising from peptic ulcers, and the problems vary according to the exact site and the morbid anatomy of the ulcers. The common esophageal ulcers in squamous epithelium associated with hiatal hernia may be very long, medium, short, or even weblike (Fig. 10), but more rarely an esophagus of normal length may be obstucted at its lower end by the fibrous reaction around a gastric ulcer very high up on the lesser curvature (Fig. 11). These all present different surgical problems and are therefore considered separately.



A. *B.*

Fig. 11.—*A*, Simple gastric ulcer high on the lesser curvature adjacent to the cardia. *B*, Three years later. Partial healing with fibrosis obstructing the esophagus.

Esophageal Stenosis From High Gastric Ulcer.—A benign gastric ulcer in a normally placed stomach, adjacent to the cardia, and causing esophageal obstruction has been encountered by the author six times. It may be difficult to be certain that the ulcer is not malignant. For this reason and because the possibility of reconstructing the cardia was not appreciated, it used to be resected, and continuity was restored by esophagojejunostomy. More recently, an effort has been made to resect the stenosis locally and to anastomose the esophagus to the stomach afresh, retaining the angle of entry, and suturing the fascia in such a way that the crus of the diaphragm encircles the lowest part of the esophagus and lies snugly in the angle between it and the fundus of the stomach. This may be illustrated by the following case report.

CASE 5.—P. T., a man aged 46, complained for eighteen months of dysphagia, belching, regurgitation of food, and "gurglings" high in the epigastrium. He had also lost weight and energy. Radiography showed the crater of a simple gastric ulcer on the lesser curvature of the stomach, at the cardia (Fig. 12). This ulcer could not be seen through the esophagoscope but the cardia was so distorted that a bougie could not be passed into the stomach. The lesion was exposed through a left thoracoabdominal incision. The esophagus looked and felt normal, but there was an induration of the stomach around the cardia. The stomach was rotated forward, the lesser sac opened, and an incision made in the posterior wall of the stomach so that the ulcer could be inspected and palpated from within. A tight

Fig. 12.

Fig. 13.

Fig. 12.—Case 5. Radiograph which shows simple gastric ulcer crater on the lesser curvature just below the entrance of the esophagus into the stomach.

Fig. 13.—Case 5. One year after resection of the cardia and reanastomosis. The depression seen just below the entrance of the esophagus into the stomach is caused by kinking and is not an ulcer crater.

fibrous stricture was felt to encircle the cardia completely, and this was associated with ulceration on its gastric side. The cardia was isolated and cleaned on the outside, and then resected. The resulting hole in the stomach was reduced in size by a few interrupted catgut stitches and then the anastomosis was made, the mucous membrane and muscle layers being joined separately by interrupted catgut. As the exploratory hole in the back of the stomach was still open, the finger was inserted here and the anastomosis felt to be quite smooth on the inside. The stomach was cleaned by suction and the hole in its posterior wall closed. The fascia of the esophagus was stitched to the under aspect of the diaphragm as in the

repair of hiatal hernia, and a gastrostomy was performed. This last was to allow aspiration of the stomach in the immediate postoperative period, for some of the vagal fibers had been cut and others almost certainly injured. The patient had a little dysphagia in the first few days after operation, intermittent slight dysphagia for solid meat during the next two months, and since then has been completely free from trouble. Dr. A. S. Johnstone examined him radiographically one year after operation, and found slight kinking at the anastomosis, no ulcer, no obstruction, and only occasional slight reflux with compression of the abdomen (Fig. 13).

Mr. G. H. Wooler has had a similar patient in whom he resected the cardia and anastomosed the esophagus to the stomach, joining the mucous membranes as far down the lesser curvature as he could, and then burying the abdominal esophagus in a tunnel of gastric muscle. Although the patient developed some fibrous stenosis, this gradually stretched until he could eat a full meal in comfort, and no reflux into the esophagus occurred.

Short Esophageal Stenosis Associated With Hiatal Hernia.—A short stenosis is taken to mean anything from a fine web to something under 1 cm. in length. Some of these strictures are obviously of the same morbid anatomy as the long ones, that is, an accumulation of inflammatory cells and fibrous tissue mainly in the submucous layer of the esophagus. There are others, however, the occurrence of which has been stressed by Ingelfinger and Kramer[1] and by Schatzki and Gary[2] and called the lower esophageal ring, where the pathology may be slightly different. A surgical approach and findings at operation in 2 patients have recently been described by Bugden and Delmonico.[3] These obstructions are of a diaphragm-like appearance, concentric, and of a constant diameter. They occur at the lower end of the esophagus and, in the patients so far observed, are associated with a sliding diaphragmatic hernia. As the symptoms in these patients are not always very severe and may, in fact, with proper mastication, be absent altogether, there has been no indication to operate upon many of them, so that the detailed pathology of the condition is still a matter for discussion. Their association with diaphragmatic hernia makes it difficult to dissociate them from esophagitis and the author's suggestion is that they resemble the webs seen in the cricopharyngeal region and that they occur by the coalescence of kissing superficial ulcers with attentuation of the fine granulations by movement, and ultimate replacement by fibrous tissue and an epithelial overgrowth. If this were true, they would differ from the short fibrous stenosis in that they result from superficial inflammation only, whereas the short fibrous stenosis results from the penetration of inflammatory processes into the submucous layer of the esophagus. The position may be a little more complicated than this for, in some patients operated upon by the author, there has been unmistakable evidence in the stricture of smooth muscle hypertrophy with or without admixture with fibrous tissue, and this in the absence of hypertrophy above the obstruction.

The surgical approach to the problem does not differ in character whether the patient presents a web obstruction or a short fibrous stenosis. It is based upon two conceptions. First, it is true that the muscular wall of the esophagus separates very easily from the mucous layer. If a longitudinal incision be made in the muscle and blunt dissection be carried out in the submucous layer, the

mucous membrane can be lifted from its coverings as an intact tube. Second, although it may be possible, in the presence of a short stenosis, to reduce a sliding hernia, competence of the cardia is not thereby attained, for this depends, not only on the position of the cardia in relation to the diaphragmatic crus, but also on the soft compliance of all layers of the esophagus at the junc-

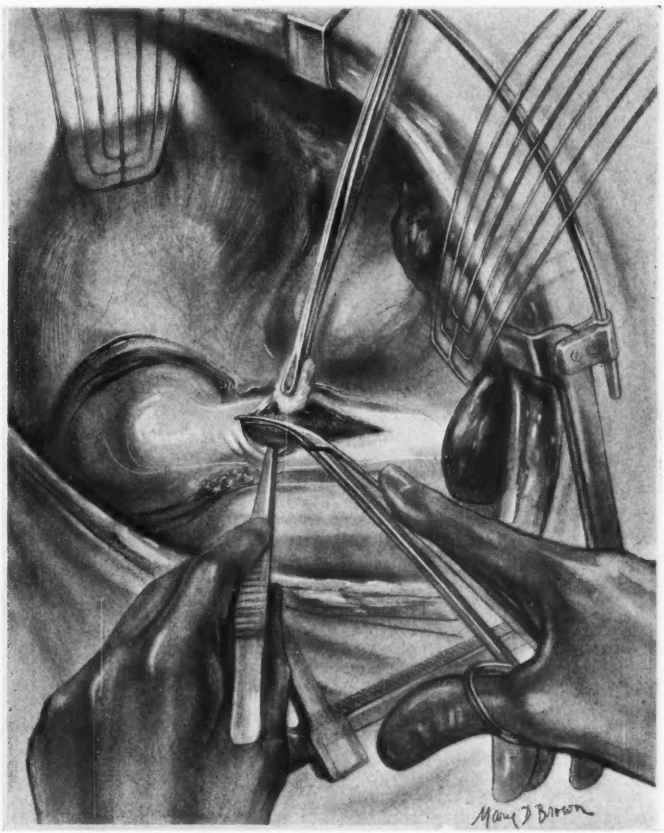


Fig. 14.—Incision of the muscular coat of the esophagus above a stricture, and its separation from the mucous membrane.

tion of this with the stomach. The presence of induration or fibrous scarring at the cardia, with the inability of the walls to collapse in response to very light pressure, will allow reflux into the esophagus with all that that entails even though the cardia is in its normal relation to the diaphragm. The operation therefore consists of resection of the submucous stricture from beneath the muscle layers.

Through a left thoracotomy incision the esophagus and stomach are isolated within the mediastinum, leaving the vagus nerves adherent. They are

rotated forward and a longitudinal incision made in the posterior wall starting 2 cm. above the cardia and passing upward for 3 cm. The incision passes down to the submucous layer; small retracting stitches are placed through the edge of the muscle, and blunt dissection carried out with fine scissors until the tube of mucous membrane is free all the way round. A string is then passed round the mucous membrane and gentle traction applied to lift it out of its bed while the incision in the muscle coat is carried down very carefully over the cardia on to the stomach. This prolongation of the incision is made with fine curved blunt-ended scissors which, in their opening action are used for blunt dissection in the submucous layer, and in their closing action cut the muscle layer. In this way the stricture is exposed (Figs. 14 and 15). It may be excised in whole or in part according to the findings at operation. The mucous

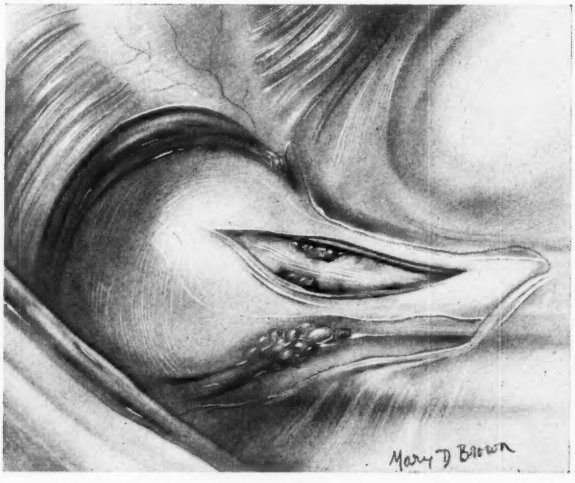


Fig. 15.—Preliminary section removed from the stricture without injury to the mucosa.

membrane can sometimes be left intact but, if injured or excised, it can be repaired with fine interrupted catgut stitches. Complete hemostasis is secured and the muscle layers lightly sutured back into place. The hernia may then be reduced, the fascial connection of the cardia repaired below the diaphragm and the hiatus closed lightly around the cardia.

CASE 6.—H. H., a man aged 59, complained of dysphagia for eight weeks. Food lodged at the lower end of the sternum causing discomfort but no pain. Regurgitation was most marked when riding in a bus after breakfast. The patient was very fat and short of breath but there were no abnormal physical findings. Radiography showed a ringlike stenosis at the lower end of the esophagus (Fig. 16). It was tight and short, and immediately below it was a pouch of herniated stomach (Fig. 17). The rest of the stomach and duodenum was normal. Esophagoscopy was difficult because of a very rigid back, but no superficial esophagitis was seen. At the lower end, a soft ulcerated stricture was seen partly obscured from above by edematous folds of esophageal mucosa. A biopsy from the stricture showed stratified squamous epithelium partly covering scarred connective tissue stroma. Operation was performed on Sept. 29, 1954, as already described. As so often happens, the exact level of the stricture could not be determined from the outside, and as a rather imperfect view had

been obtained through the esophagoscope, a stomach tube was passed. This became impacted 2 cm. above the apparent cardia at the level where the phreno-esophageal ligament was reflected from the surface of the esophagus. When the muscle layer had been separated, a thick ring of fibrosed muscle was found at the site of the stricture. A section of this was excised over about one half the circumference of the esophagus and sent for histology. It showed smooth muscle with some fibrous tissue replacement and a few nerve fibers. The

Fig. 16. Fig. 17. Fig. 18.

Fig. 16.—Case 6. Radiograph which shows weblike obstruction of the lower end of the esophagus associated with sliding hiatal hernia.

Fig. 17.—Case 6. A herniated stomach, not demonstrated on the previous film, is now clearly visible.

Fig. 18.—Case 6. A postoperative film. There is still slight ring formation present above cardia but this area expanded readily to the passage of a bolus and in the absence of reflux seems unlikely to deteriorate.

mucosa was opened so that the inside could be inspected. There was superficial ulceration at the site so that the exact position of the gastric mucosa could not be determined. A biopsy above the stricture showed stratified squamous epithelium; at the stricture there was connective tissue with fibrosis and chronic inflammation, a little smooth muscle, and a fragment of squamous epithelium; and below the stricture edematous connective tissue. Much fat was excised from the cardia, and the hernia treated. A temporary gastrostomy was performed so that the stomach could be kept aspirated after operation. The patient was completely relieved and a barium examination two months later showed no obstruction, no dilatation, the cardia in its proper position, and no reflux (Fig. 18).

CASE 7.—S. L., a man aged 55, had dysphagia for fifteen years and radiographs showed a ringlike constriction at the lower end of the esophagus (Fig. 19), and a sliding hernia, with

the cardia 5 cm. above the hiatus. At esophagoscopy the obstruction looked like a web through which a small swab could be passed and withdrawn. As this was done, the web was pushed down or dragged up by the swab and was felt to be very resilient. An operation similar to that described above was performed. The presence of a hernia was confirmed (see Fig. 14). There was no hypertrophy of the muscle above the stricture and the obstruction itself was found to be caused by a thickened band of circular muscle immediately above the stomach, 7 mm. long and 3 to 4 mm. on cross section (see Fig. 15). It felt slightly fibrous when cut, but histologic examination showed only hypertrophied smooth muscle. The hernia was reduced. The patient remained free from symptoms and the cardia was shown to be competent when examined radiographically (Fig. 20).

Fig. 19. Fig. 20

Fig. 19.—Case 7. Lower esophageal ring.
Fig. 20.—Case 7. Radiograph which shows appearance after operation. No obstruction and no reflux.

CASE 8.—B. B., a woman aged 56, had had severe heartburn and vomiting with each of three pregnancies. After that she had no discomfort until the age of 47 when she had pneumonia followed by heartburn and epigastric discomfort. After a strangulated inguinal hernia at the age of 52, she complained of persistent epigastric and retrosternal pain going through to the back but not related to swallowing, attacks of vomiting which was often intensely acid, and dysphagia for solid food that had not been very well masticated. Radiography showed a sliding hiatal hernia with some rigidity of the lower end of the esophagus (Fig. 21). Although fluid barium passed through easily, this part did not dilate like the rest of the esophagus. The lowest 4 cm. of the esophagus was seen at esophagoscopy to be red-raw. Just above the mucous membrane of the herniated stomach, there was a crescentic fold on the posterior wall. It was tough but short and a swab could be felt to flip over it.

The operation already described was performed for this patient. There was no obvious hypertrophy of the muscle of the esophagus. Lying transversely in the submucous layer immediately above the cardia, and corresponding to the fold seen at esophagoscopy, was a pale cream-colored structure looking like a cylinder of rolled-up fibrin. It was firm to the touch and separated from the overlying muscle and adjacent areolar tissue with great ease. Its surface seemed quite smooth. It was removed without injury to the mucous membrane, and on histologic section was seen to be a mixture of fibrous tissue and smooth muscle with a whorled arrangement reminiscent of a uterine fibroid. The hernia was reduced and the patient remains free from symptoms with a competent cardia.

Fig. 21.—Case 8. Radiograph which demonstrates sliding hernia with rigidity of the lower end of the esophagus.

Medium-Length Esophageal Stenosis Associated With Hiatal Hernia.—A medium-length stenosis is considered as one between 1 and 2 cm. long. In this group only one patient has been treated by the author by submuscular resection of the stenosis. The operation was performed as described for short stenosis except that, when the muscular coats had been reflected, the stricture was completely excised and the mucous membrane of the esophagus united to that of the stomach by a row of fine interrupted catgut sutures. A more extensive mobilization of the esophagus was necessary in order to replace the cardia below the diaphragm. Unfortunately, this patient had bullous emphysema of both lungs with severe respiratory incapacity and he died from acute cor pulmonale eight days after operation. The respiratory difficulty was the stimulus to try to do a conservative operation for it was thought that with the aid of a tracheostomy he might survive this whereas he would not tolerate a major resection with esophagojejunostomy. No conclusions can be drawn from this as

the time was not long enough to estimate competence. The obstruction was, of course, relieved and the cardia was held by the diaphragm, but these are not sufficient criteria to indicate success.

Mr. G. H. Wooler has treated a similar stenosis by total rather than submuscular local resection, with esophagogastrostomy and reduction of the hernia. Although this patient made good progress in eating he did develop a further fibrous stenosis that had to be dilated at intervals. From this very limited experience, no final conclusions can be drawn but it seems worth further development to see if a competent cardia can be fashioned.

Long Esophageal Stenosis With Hiatal Hernia.—Any stricture more than 2 cm. in length is considered to be a long one and there seems to be no alternative to resecting these if the patient is fit for anything more than gentle esophagoscopic dilatation from time to time. The problem is presented most urgently when it occurs in young children, for in them the complete destruction of the cardia and lower esophagus leaves no hope of a conservative approach at a time in life when it is most desirable. This is a subject for separate discussion, but it may be mentioned here that just as the limits of surgery are defined, not by anatomy, but by physiology, so our results must be judged by the preservation of physiology even when this is at the expense of anatomy. The resection of a long esophageal stricture, the reduction of the stomach into the abdomen, and restoration of normal continuity by an isolated intestinal loop as recommended by Brain[4] would appear to do this, and has in recent years been adopted by the author as the operation of choice.

SUMMARY

1. The importance of the preservation of the function of the cardia in benign lesions is stressed.

2. A conservative approach should be made in cardiospasm, hiatal hernia, lower esophageal web, and short esophageal stenosis. It may occasionally be applicable to obstruction by benign gastric ulcer. Illustrative case reports are given.

3. With improved technique it may be possible to retrieve the situation for strictures for medium length (1 to 2 cm.), but for longer ones there seems to be no alternative to excision and intestinal replacement.

4. It is sometimes possible to restore function to a cardia that has been rendered incompetent by surgical trauma, and such a procedure is described.

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THE INFLUENCE OF HISTOLOGIC TYPE ON SURVIVAL FOLLOWING RADIOTHERAPY OF BRONCHOGENIC CARCINOMA

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FROM the large volume of literature which has been written concerning the radiotherapy of bronchogenic carcinoma, there has emerged only a few conclusions about which there is general agreement. Almost all of the papers written about this subject agree that radiotherapy never cures carcinoma of the lung; in fact, there are very few patients who have survived more than five years following treatment. A second conclusion about which there is general but not unanimous agreement is that radiotherapy seems to prolong life even though this is often for several months only. It is important when comparing statistics that the survival time be defined in the same fashion by all therapists. In reviewing the literature, it is evident that this definition varies with the author. Some authors consider the survival time as the time between the onset of symptoms and the death of the patient; other authors express survival time as the period of time between diagnosis and death; and a third and fourth group express survival time as the time between the onset of treatment or the termination of treatment and death, respectively. All survival times presented here will be that period of time between the first treatment and the death of the patient. This time interval is the most logical one because the effect of radiation therapy on the lesion begins at the time of commencement of therapy and it is the effect of radiation therapy on the patient's survival which is being evaluated in this paper. Almost every other conclusion concerning the radiotherapy of bronchogenic carcinoma is a controversial one. One of the more controversial subjects is the relationship of survival time to tumor dose. One author, Tenzel,[11] believes that survival time increased with an increase in total tumor dose. Adelman,[1] on the other hand, feels that when his own series of cases was analyzed statistically, there was no increase in the survival time with an increase in the total tumor dose. Some authors have pointed to the relationship between histologic type and survival time, but this relationship has, in general, been minimized in the radiologic literature with only a few authors commenting on its importance. In studying the series of cases presented here, the role of histologic type in prognosticating survival emerged as the most important one of all.

MATERIAL SOURCE

Seventy-four patients with clinically or histologically diagnosed intrathoracic mass lesions were referred to the Department of Radiotherapy of the Allegheny General Hospital between March 1, 1952, and March 1, 1955. Twenty-four patients had to be discarded from this group for the following

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reasons; 15 patients received only a few treatments in our department and then left the hospital to be treated in other cities, 2 patients with pleural effusion were treated with radiogold, and 7 patients had excellent clinical evidence of bronchogenic carcinoma but the diagnosis was not proved histologically. Thus, there remained 50 proved cases of bronchogenic carcinoma for study. All 50 of these patients were treated on a 400 kv. constant potential x-ray generator. The half-value-layer of the beam was 6.5 mm. Cu. With a beam of this quality, 5,000 to 6,000 r can be delivered to the tumor through two or three ports.

The 50 cases were divided into histologic groups as shown in Table I.

TABLE I. HISTOLOGIC DISTRIBUTION OF CASES

Undifferentiated carcinoma	20
Squamous-cell carcinoma	18
Adenocarcinoma	3
Malignant but cell type unknown	9

UNDIFFERENTIATED CARCINOMA

Analysis of the undifferentiated group comprising 20 patients proved the ineffectiveness of treatment of this type of bronchogenic carcinoma (Table II).

TABLE II. UNDIFFERENTIATED CARCINOMA GROUP

Number of patients in group	20
Number of patients followed	18
Number of patients dead	17
Number of patients living	1
Number of one-year survivals	0
Percentage of cases surviving one year	0%
Number of patients with metastases before treatment	9
Percentage of patients with metastases before treatment	45%
Average survival time of dead patients in months	4.7

The average age of this group was 55 years. The average duration of time between the onset of symptoms and the diagnosis was 2.4 months. Node metastases outside of the thorax were present at the time of diagnosis in 9 of these 20 patients, or 45 per cent. Not a single one of these patients survived over eleven months. The average survival time for the 17 patients who are known to be dead was only 4.7 months. One patient is still alive three months after treatment and 2 of the cases have no follow-up information but both were in very poor condition at the completion of their treatment and they are presumed to be dead. Five patients received over 5,000 r tumor dose, four received between 4,000 and 5,000 r, six received 3,000 to 4,000 r, and the remaining 5 received less than 3,000 r tumor dose. The average survival time of the patients receiving more than 5,000 r was 4.8 months which is almost identical to the average survival of the entire group; therefore, it appears that there is in our series no demonstrable correlation between total dose and survival time in this group.

SQUAMOUS-CELL CARCINOMA

The results obtained by the radiation treatment of this group with squamous-cell carcinoma was more encouraging than the preceding one (Table III). The average age of this group was identical with that of the undifferentiated group. The average duration of time between the onset of symptoms and the diagnosis

was 2.9 months which is similar to the undifferentiated group. Known metastases outside of the thorax were present in only 11 per cent of this group as compared to 45 per cent in the anaplastic group. Fifteen of the 18 patients are dead and 8 of these survived longer than one year. The percentage of one-year survival among the dead patients was 53 per cent. The average survival time of the deceased patients was 11.4 months. This is approximately seven months longer than the average survival time for the deceased members of the preceding group. Four of the dead patients survived eighteen months and 1 survived twenty-four months. There is a two and one-half year survival among the 3 living patients and the remaining 2 are alive eleven months and four months posttherapy, respectively.

TABLE III. SQUAMOUS-CELL CARCINOMA GROUP

Number of patients in group	18
Number of patients followed	18
Number of patients dead	15
Number of patients living	3
Number of one-year survivals among dead	8
Percentage of patients dead surviving over one year	53%
Number of patients living and dead surviving one year	9
Percentage of patients living and dead surviving one year	50%
Number of patients living and dead surviving 18 months	5
Percentage of patients living and dead surviving 18 months	28%
Number of patients living and dead surviving 24 months	2
Percentage of patients living and dead surviving 24 months	11%
Number of patients with metastases before treatment	2
Percentage of patients with metastases before treatment	11%
Average survival time of dead patients in months	11.4

Seven of the 18 patients received over 5,000 r tumor dose, 7 received between 4,000 r and 5,000 r, 1 received between 3,000 r and 4,000 r, and the remaining 3 received less than 3,000 r. It is difficult to draw any conclusion concerning the relationship between total doses and survival time in any series of cases because there are many immeasurable factors which affect survival time. Among these factors are the extent of the tumor, the presence of metastases, the location of the tumor, and the condition of the patient. Dosage rate is another measurable factor which is as important as total dose; yet, it is completely ignored when survival time is plotted against total dose. Because of these factors, the conclusion that the survival time among patients treated with doses in excess of 5,000 r was 14.1 months while the over-all survival time for the whole group was 11.4 months is of doubtful significance.

ADENOCARCINOMA

The average survival time for this group was 8.3 months. No other fact is worth mentioning because of the small size of this group.

HISTOLOGICALLY UNKNOWN GROUP

The survival time in this group of 9 patients was only 4.6 months. This is as poor as the undifferentiated group. The reason for this poor survival is not apparent but it is probably due to the fact that many of these patients were in very poor condition when seen and the diagnosis had to be made on the microscopic examination of the bronchial smears.

COMMENT

From the statistics presented here there is no doubt that the survival time following radiation therapy is much longer for squamous-cell carcinoma of the lung than for undifferentiated carcinoma (Fig. 1). The average survival time is

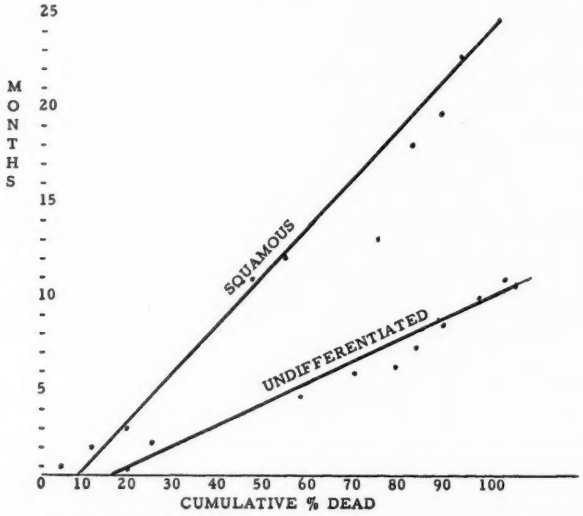

Fig. 1.—A graph demonstrating the rapidity of death in patients with undifferentiated carcinoma compared with the patients with squamous-cell carcinoma.

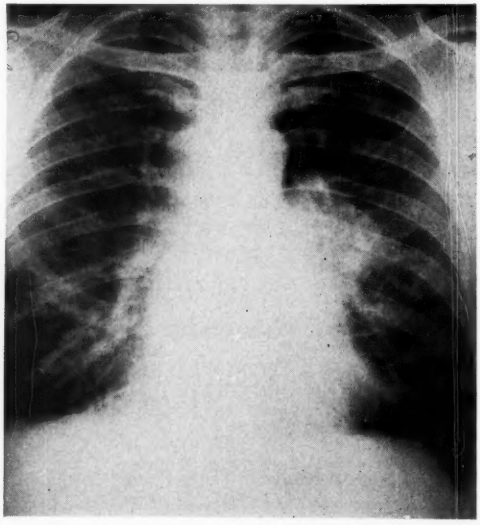

Fig. 2.—Chest roentgenogram of patient with undifferentiated carcinoma demonstrating the tumor before treatment. There is involvement of the central portion of the left lung and a rounded mass protruding from the right side of the mediastinum at the level of the aortic arch.

over twice as long for the squamous-cell group as it is for the anaplastic group. The one-year survival rate is 0 per cent for undifferentiated carcinoma and 53 per cent for the squamous-cell lesions. The eighteen-month survival rate

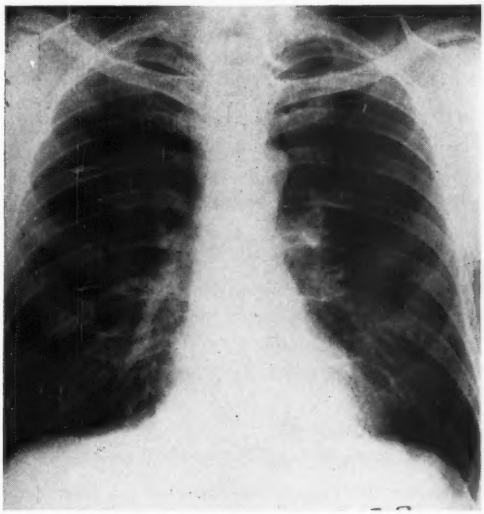

Fig. 3.—Chest appears normal after 3,471 r had been delivered to the tumor in fifty days.

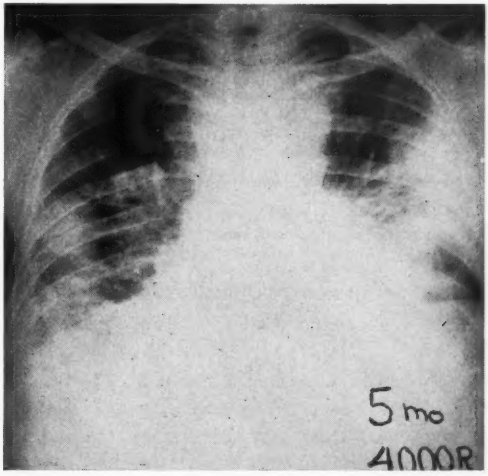

Fig. 4.—Roentgenogram taken five months after treatment. Tumor has recuperated and is now growing wildly throughout the chest.

for squamous-cell carcinoma is 27 per cent. Although we did not have a control group of untreated cases, the literature has many reports of control groups and few patients with bronchogenic carcinoma survive one year after diagnosis without any form of therapy. The fact that we obtained a 53 per cent one-year

survival rate after treatment indicates that squamous-cell lesions are benefited by radiation therapy. It would then seem to follow that the treatment of squamous-cell carcinoma by radiotherapy should be carried out as vigorously as possible. This does not hold true for the undifferentiated lesions. The survival time in this group is very poor and it is doubtful that radiation therapy increases the survival time. There are three factors which account for the poor prognosis in anaplastic carcinoma:

1. They metastasize early as illustrated by the presence of metastases outside of the thorax in 45 per cent of the cases treated.
2. They are rapidly growing and by nature extremely invasive.
3. Although radiosensitive, they are also rapidly recuperable (Figs. 2, 3, 4).

SUMMARY

Vigorous radiotherapy to squamous-cell carcinoma of the lung is justified by the increased survival time in treated patients. On the other hand, radiotherapy of undifferentiated carcinoma should be reserved for the localized inoperable lesion and it is of doubtful value even in this selected lesion.

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A DIRECT EXPERIMENTAL APPROACH TO THE AORTIC VALVE
II. ACUTE RETROPERFUSION OF THE CORONARY SINUS

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DIRECT or "open" intracardiac surgery has evolved very rapidly within the past five years. During this period it has made the important transition from a limited experimental approach to a widely applicable clinical procedure.[1, 2]

Two basic techniques have been developed by workers who endeavor to operate within the heart and correct congenital defects, or acquired valvular lesions, under direct exposure.

The first technique employs the use of hypothermia to lower the metabolic needs of the body. In this way the cardiac pump action can be dispensed with temporarily and the circulation stopped during the intracardiac operative episode.[3, 4] Under these circumstances the surgeon has a limited time for intracardiac manipulations.[5, 6] After this, the cardiac pump action must be restored if the metabolic debt is to be reversible, and the vital organs are to survive. Aside from the time limitation, hypothermia is frequently attended by certain side effects which have been considered undesirable. The most important of these is ventricular fibrillation. Intensive research is under way in order to gain a more adequate understanding of the body reactions in hypothermia[7] and, also, to devise means of preventing and treating these undesirable phenomena.

The second "open" technique is one in which the heart and lungs of a normothermic subject are by-passed by a mechanical pump oxygenator,[8, 9] or by the heart and lungs of a donor[10] (cross circulation), and the greater as well as the coronary circulation are supported by an aortic perfusion of arterial blood (from pump oxygenator or donor) at adequate pressures.

None of these techniques has achieved isolation of the heart in vivo. By this we mean complete independence of this organ from the greater circulation perfusion system.

Again, none of these methods has succeeded in allowing an approach to the region of the aortic valve with impunity. Entrance into this region exposes the coronary ostia to the free air with resulting coronary air embolism, ventricular fibrillation, and death. If entry is attempted while aortic perfusion is going on, immediate death would result from massive bleeding and loss of perfusion pressure.

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During the past year, a series of experiments[11] has been carried out in this laboratory with the aim of developing a technique whereby the following criteria were satisfied:

1. Isolation of the heart from the greater circulation. This involves maintenance of the greater and of the coronary circulation by independent means.
2. Development of a technique whereby entrance into the region of the aortic valve and exposure of the coronary ostia would not be accompanied by air embolism.

This report concerns the development of a method which meets these criteria successfully. It makes use of procedures which have been widely known and accepted for many years as well as of others of relatively recent vintage. The greater circulation is maintained throughout by the employment of a cross circulation setup very similar to the one described by Lillehei and his colleagues[10] and the use of information (regarding volume of perfusion) collected by Andreasen and Watson.[12] The coronary circulation is maintained by the application of principles based on observations by Pratt,[13] Roberts[14] and Beck and co-workers[15] to the effect that successful perfusion of the myocardial capillary bed can be carried out through retroperfusion of the coronary sinus.

The observation of retrograde flow in the coronary arteries, in such a coronary sinus retroperfusion preparation, has been made by Eckstein,[16] and by Bakst, Adam, Goldberg, and Bailey.[17] It has been used as a measure of the success of myocardial perfusion. These observations warranted the assumption that if such a retrograde flow occurred, exposure of the coronary ostia during sinus retroperfusion would be innocuous from the standpoint of the occurrence of air embolism. This assumption is borne out by the present work.

METHOD

Three adult mongrel dogs were anesthetized by the administration of 30 mg. of Nembutal, per kilogram of weight, intravenously. Intratracheal intubation was performed on all 3 animals and they were connected to mechanical respirators. Catheterization of peripheral blood vessels was carried out as follows:

Dog A (Subject): No. 10 Fr. plastic "oxygen" catheters were introduced into the right carotid artery and into the right external jugular and femoral veins. The tips of the venous catheters were placed about 3 cm. away from the entrance of the superior and inferior venae cavae into the right atrium.

Dog B (Donor No. 1): No. 10 Fr. plastic "oxygen" catheters were placed in the right (or left) femoral artery and vein.

Dog C (Donor No. 2): A No. 10 Fr. plastic "oxygen" catheter was placed in the right (or left) femoral artery.

All catheters were filled with heparin solution, clamped, and secured in place.

A right thoracotomy incision through the fourth or fifth intercostal space was performed on Dog A, and the cardiac inflow tracts were controlled by ligation of the azygos vein in continuity, and by-passing tapes around the

superior and inferior venae cavae near their entrance into the right atrium, proximal to the tips of the aforementioned venous catheters. The aorta was dissected free just above its origin so that it might be cross clamped about 5 to 6 cm. above the valvular level. A purse-string suture was placed around the tip of the right auricular appendage and a short plastic catheter introduced through the tip of the appendage and directed with the aid of a guide into the coronary sinus. Its tip came to lie about 1.5 cm. inside the sinus, the guide

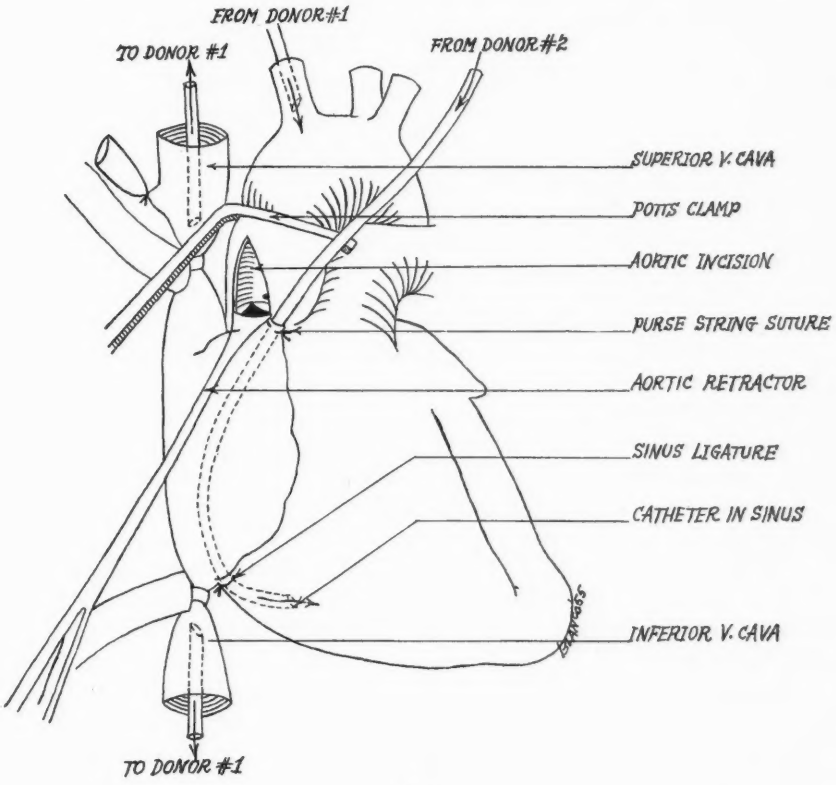

Fig. 1.

was withdrawn and the catheter was anchored in place by tying the aforementioned purse-string suture, and by placing an encircling ligature around the coronary sinus and its indwelling catheter, distal to the entrance of the sinus into the right atrium. The catheter was filled with heparin solution and clamped (See Fig. 1).

Dogs A and B were then joined by a cross circulation setup powered by a double Sigmamotor pump, in which venous blood was extracted from Dog A via the catheters placed in the external jugular and femoral veins, and was in-

jected into Dog B's femoral vein. Arterial blood was returned from Dog B into Dog A's carotid artery. The pumps had been previously set to deliver approximately 200 c.c. of blood per minute.

After these connections were made, taking care to eliminate all air bubbles from the system, the cardiac inflow tract of Dog A was closed by tightening the tapes around both venae cavae and the pumps were started. At this point the respirator was disconnected from Dog A allowing the lungs to collapse. The cross circulation preparation was then complete.

After a brief period (1 to 2 minutes) to allow for a thorough check of all connections and assure good functioning of the cross circulation, the catheter in Dog C's femoral artery was connected to the catheter in Dog A's coronary sinus after graduating the flow through the connecting tube so that about 50 c.c. of arterial blood per minute was delivered. The clamp was taken off the coronary sinus catheter and sinus retroperfusion became evident: The epicardial veins coursing over the right ventricle became red, the heart which had become smaller and almost empty during the cross circulation period, appeared fuller.

A Potts' curved clamp was then quickly placed across the aorta about 5 cm. above its origin and, before the vessel had a chance to dilate too much, a longitudinal incision was made along its anterolateral surface. This incision was about 2 cm. in length and started just above the sinuses of Valsalva. The greater circulation was sustained at this point by the cross circulation perfusion while the myocardial circulation was sustained by retroperfusion of the coronary sinus. A small jet of blood escaped from the aortic incision and subsided as soon as the latter was enlarged. If the coronary sinus retroperfusion was successful the heartbeat was forceful and the epicardial veins maintained their bright red color.

A small retractor was inserted into the aortic incision and the superior valvular surfaces were inspected. The coronary ostia were also visualized. With the help of moderate suction the field could be kept fairly dry and exposure was good.

During this time it was well to check on the condition of Dog C and make sure that he was tolerating well the bleeding into Dog A's coronary sinus. If any weakness of Dog C's peripheral pulses was noted or if the sinus perfusion appeared to be deteriorating, as evidenced by a darkening of the epicardial veins, steps were taken to close the aortic incision and return the heart to the cross circulation perfusion system. A period of 5 minutes was well tolerated, at the end of which the incision in the aorta was closed (allowing all air to escape the left ventricle before placing the final suture) and the cross clamp was removed. This restored continuity between coronary and greater circulations. A clamp was then placed across the sinus catheter.

The epicardial veins resumed their dark color almost immediately. After a short wait of 1 to 2 minutes during which the heart was observed for any evidence of coronary air embolism, arrythmias, weakness of contraction, etc.,

the cross circulation was stopped, the cardiac inflow tract was released, and the lungs were re-expanded followed by connection of the intratracheal tube to the mechanical respirator.

The coronary sinus catheter was pulled out, and the tip of the auricular appendage was ligated. The aorta was inspected for evidences of bleeding. The pleural cavities were sucked dry. The chest was closed in layers leaving a No. 18 Fr. rubber catheter, with multiple holes, in the chest to be attached to suction during the immediate postoperative period. Electrocardiographic tracings of Dog A were taken before and after the operative procedure. They were repeated twenty-four hours after the operation.

DISCUSSION

During the preliminary stages of this project, 20 dogs were operated upon and various modifications of approach, times of inflow occlusion, and intra-aortic maneuvers, were tried. Many of the experiments were acute in nature and, in many, the aorta was left open as long as the heart was beating regularly in order to determine the maximum time available for direct valvular manipulation. As can be expected, the mortality was extremely high in this group and only 3 animals survived these procedures.

After our present approach was perfected 11 dogs were operated upon, and these comprise the series which concerns this report. The time during which the animals were kept on cross circulation, the time spent in intra-aortic maneuvers, and the survival rates are detailed in Table I.

TABLE I. DATA ON CROSS CIRCULATION, AND INTRA-AORTIC VISUALIZATION TIMES, AND ON SURVIVALS

DOG	TIME ON CROSS CIRCULATION (MIN.)	TIME FOR INTRA-AORTIC MANEUVERS (MIN.)	SURVIVAL (4 OR MORE DAYS)
S21	14	3½	Survived
S22	17	6	Survived
S23	-	-	Died at operation
S24	12	5½	Survived
S25	11½	4¾	Survived
S26	16½	6¼	Survived
S27	15½	7¼	Survived
S28	14	4	Died 24 hours
S29	14	6	Survived
S30	16	7	Survived
S31	16	7	Survived

One dog (S23) died on the operating table from a preventable error. In this animal, the coronary sinus catheter became dislodged, and upon attempting to replace it undue force was used and the metal guide used for placing it penetrated the ventricular myocardium, and perforated the ventricle. Perfusion with the catheter in the myocardium was unsuccessful and ventricular fibrillation followed.

Another dog (S28) died twenty-four hours after the procedure was completed. In this animal, considerable trouble was experienced with the cross circulation setup, presumably because of clotting in the connecting tubing, with

collapse of the latter, and inefficient perfusion. Intra-aortic maneuvers had to be interrupted but in spite of this, cerebral anoxia must have occurred before the cardiac inflow could be opened and breathing with the aid of the respirator carried out.

In the remaining 9 animals, adequate myocardial perfusion was obtained for periods ranging from 3½ to 7 minutes (an average of 5 minutes) during which the superior surface of the aortic cusps and the coronary ostia were inspected directly, while the aortic wound was maintained wide open by the intra-aortic retractor. There were no instances of air embolism or fibrillation and it was not necessary to employ cardiac massage or drugs to strengthen or aid the cardiac contraction at any time. We have mentioned the weakening of the pulses of the second donor dog (Dog C) as the factor that made us interrupt our perfusion in every instance. Concomitantly with this change the coronary sinus perfusion would also deteriorate, and the myocardial contraction in Dog A would falter perceptibly. It is felt that the use of more than one donor for this purpose or the use of a reservoir of oxygenated blood would prolong the time of myocardial perfusion and consequently the period available for intra-aortic maneuvers.

SUMMARY

An experimental method has been described whereby complete independence between the systemic and coronary circulations can be achieved and the two may be maintained simultaneously during total cardiac by-pass.

Retroperfusion of the coronary sinus is used to maintain the nutrition and oxygenation of the myocardium.

The method described allows entry into the aorta just above the valvular level, with direct intra-aortic visualization of the superior surfaces of the aortic ostia, without danger of coronary air embolism or other dangerous sequelae.

Eleven dogs have been operated upon by this technique with two deaths within forty-eight hours after the operation. These deaths can be attributed directly to avoidable technical errors.

It is believed that the limited time (about 7 minutes) available, at present, for intra-aortic maneuvers, can be extended substantially by feasible improvements in this method. Further experiments are being undertaken to this effect and will be the subject of future communications.

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DECORTICATION IN PRIMARY TUBERCULOUS PLEURITIS AND EMPYEMA WITH A STUDY OF FUNCTIONAL RECOVERY

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THE procedure of removing a thick inflammatory tuberculous peel from the lung has been reported by many authors.[9-11, 14, 17, 18] Technically it is more difficult than decortication following traumatic hemothorax. Even if there is frank empyema, most of the wounds heal without infection and few redevelop an empyema. The majority of the previously reported cases of surgical decortication represent empyema, or inexpansible lung with residual pleural spaces, following therapeutic pneumothorax. Few have reported more than 1 to 7 cases of decortication for organized tuberculous pleuritis and empyema as a sequela to pleural effusion. Tuttle's series of 43 patients had only 7 who represented decortications for tuberculous pleuritis and effusion with encased lung.[16] No pulmonary function studies were reported. In a series of thirteen decortications reported by Falk, Pearson, and Martin, four were for sequelae of tuberculous pleurisy with effusion.[6] Function studies were reported. In a report of sixty-six decortications by the Subcommittee on Surgical Treatment of Diseases of the Chest (American College of Chest Physicians), only three were simple decortications for tuberculous empyema.[1] Results were good in two, fair in one. Fifty-one decortications performed on 49 patients with tuberculosis were reported by Ellis from the Mayo Clinic.[5] In only 1 of 7 patients with tuberculous empyema was the disease primary, in the others it resulted as a complication of an inexpansible lung after pneumothorax. One other patient underwent decortication for pleurisy with effusion but this was three years following thoracoplasty.

It is the purpose of this article to report on 16 cases of organized tuberculous pleuritis, following effusion, treated by visceroparietal decortication; no other surgical procedure being carried out in conjunction with this operation.

Patients who develop primary tuberculous pleural effusions follow one of three courses on drug therapy. The effusion may resolve rapidly with or without multiple thoracenteses. Resolution may be slow with gradual formation of a thick, fibrotic pleural peel. A more violent inflammatory reaction may produce a thick peel which in certain areas will caseate extensively and be associated with frank pus with or without a bronchopleural fistula. The latter is what is commonly accepted as tuberculous empyema. The response, we

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believe, depends chiefly upon the pathogenic vigor with which the subpleural active caseous focus seeds the pleura. The initial serous effusion may well be a transudative response to tuberculous inflammation in the subpleural lymphatics, but as the tuberculous inflammation, with its bacterial inoculum reaches the pleural space, fluid that originally is abundant, serous, of low specific gravity, and nonsanguineous often becomes thick, flocculent pus unobtainable by thoracentesis. A heavy opacity on roentgenograms in the dependent portions of the lung field results. The pleural peel often persists despite attempts at medical débridement by the use of proteolytic enzymes. Active tuberculosis is not a contraindication to their use.[12, 15] The early and efficient use of the enzymes and aspiration will make surgical decortication necessary less frequently. Fluid may become nonaspirable either because of coagulation, or because of its loculation and fibrin content. Even though all fluid may seem to disappear, the inflammatory build-up of the pleural peel may continue because of the extensive caseous tuberculosis of the peel itself. The presence of such a thick membrane, with or without fluid, encases the lung in an unyielding cuirass which may render the lung totally incapable of respiratory exchange.

Early, Wright showed, by bronchospirometric determinations, that following re-expansion of lung tissue and restoration of normal or near normal ventilatory function, impairment may remain in pulmonary circulatory function.[18] A barrier at the alveolar wall by histologic alteration in the collapsed segments is postulated. Uninvolved, healthy lung recovers its function in large measure. Diseased lung, initially compressed therapeutically and later released by decortication, is not likely to recover any large measure of function. This is confirmed by the outstanding work of Patton, Watson and, Gaensler who showed that restoration of function after decortication was closely related to the presence or absence of pre-existing disease in lung parenchyma.[13] It may be difficult to establish the extent of destructive disease in the lung parenchyma obscured by the radiopaque pleural peel. Sputum studies, bronchoscopic and gastric washings, and tomography are of aid in estimating parenchymal involvement.

MATERIAL

Sixteen primary decortications on 15 patients were done between January, 1949, and December, 1953, and form the basis for this report. One of us, (F. J. J.) performed fifteen of the sixteen operations. In 1 patient both sides were decorticated with an interval of four weeks between operations. These were all done at Firland Sanatorium, Seattle. All of the patients operated upon had an original diagnosis of tuberculous pleural effusion resulting spontaneously and not as any therapeutic or diagnostic complication. There was minimal to moderately advanced parenchymal involvement in 10 patients, 4 of whom had positive sputum at the time of admission to the sanatorium. Seven (47 per cent) had bacteriologically positive effusions. Prior to January, 1952, streptomycin and PAS were used only during the initial preoperative and postoperative period for thirty days. Seven patients were treated in this

manner. After this date, drug treatment was started shortly after admission, continued through the surgical period until discharge and in some patients not yet concluded. Multiple aspirations were done on all patients initially until no fluid could be obtained. Seven patients underwent surgery less than six months after admission while 8 had an average interval of twelve months between admission and decortication. Eleven of the 15 patients were under 35 years of age. There was no mortality. No empyema spaces persist to our knowledge.

Specific indications for surgery were (1) persistent febrile course, (2) persistent empyema in spite of vigorous medical therapy, (3) size and extent of the encasement, (4) significant reduction of lung function, and (5) failure to improve on conservative measures. Control of the underlying parenchymal disease was considered satisfactory for the ensuing operative procedure.

RESULTS

Thirteen of the 16 patients were classed as excellent in considering only the final appearance of the roentgenograms, 2 were classified as fair, and 1, poor. Schemograms (Fig. 1) show the pre- and postoperative results by reproducing the x-ray densities in shaded areas as closely as possible.

Incomplete resolution of the radiopacity was closely related to the fair to poor postoperative courses. The correlation was, however, not exact. Significant postoperative complications occurred in 4 patients. These are stated in brief in Table I.

TABLE I

PATIENT	COMPLICATIONS	POSTOP. COURSE	X-RAY RESULTS
D. P.	Alveolopleural leak with hydropneumothorax, 8 days postop. Treatment: Reinsertion of tube	Fair	Poor
F. L.	Severe hemothorax with resultant fibrothorax despite enzymatic débridement	Poor	Fair
G. P.	Infected sinus tract after reinsertion of tube for spontaneous evacuation of intrapleural blood, 7 days postop.	Fair	Excellent
C. N.	Tube reinsertion for pneumothorax	Fair	Fair

The necessity for re-establishing suction drainage of the pleural space by closed thoracostomy prolonged convalescence only slightly and was effective in obliterating the pleural space in that no patient developed a persistent empyema. Patient D. P., who represents the single poor x-ray result, was lost to follow-up after three months. It is possible that his present status may be much improved.

Technical Considerations.—Though the principle is the same, decortication of tuberculous peel to re-expand the underlying lung differs from the original decortication procedure for inexpansible lung following clotted hemothorax as described by Burford, Parker, and Samson.[2] The partially organized peel of the clotted hemothorax need not be totally excised; only that portion of the

visceral pleura overlying the lung is stripped away, freeing the lung for re-expansion. The parietal pleural peel seems largely to resorb within a few weeks once the hemothorax is obliterated. In the case of the tuberculous peel,

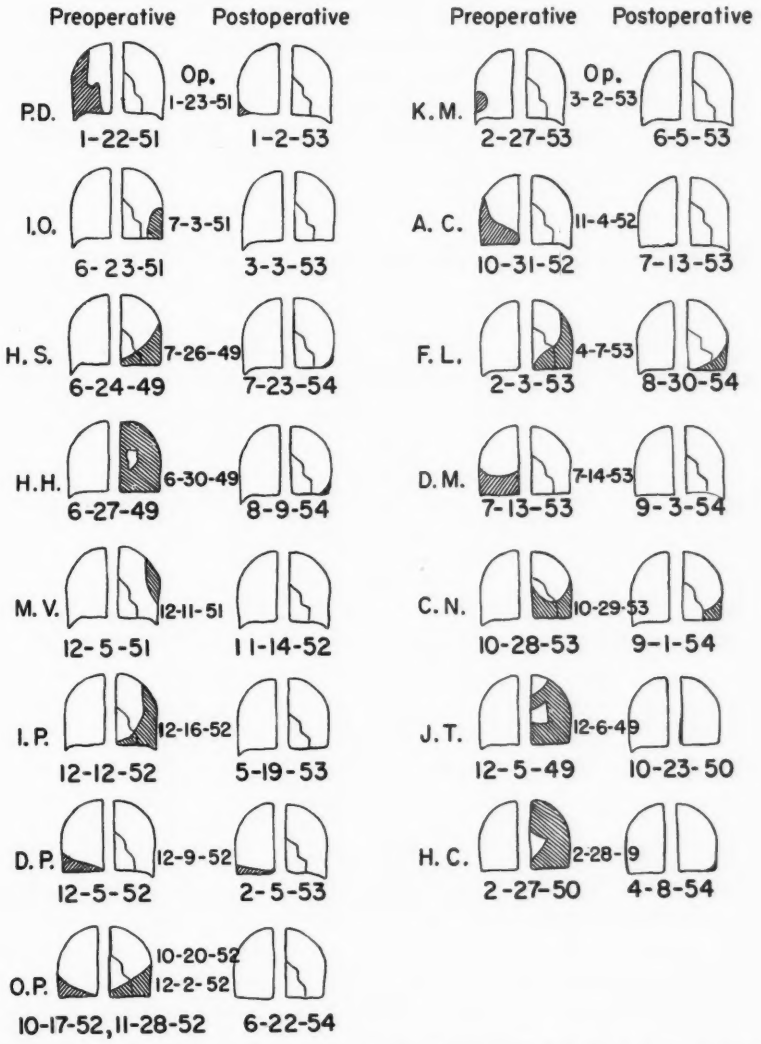


Fig. 1.—Composite drawings from preoperative and postoperative x-rays of 15 patients with tuberculous pleuritis.

we are dealing with a much more completely organized, densely fibrous structure, covering both viscera and parietal structures. The peel itself frequently contains large areas of conglomerate caseation, more particularly as

the diaphragm is approached, as if gravity played a part in the more intense tuberculous involvement of the lower thorax. In contrast, the pleural peel covering the mediastinal surface is customarily thin and fortunately strips relatively easily. The ideal (unfortunately not often attained) is a complete excision of the pleural sac intact (see Fig. 2, *A* and *B*). In any case, it is imperative in achieving a good functional result that the parietal and phrenic pleural peel, as well as the visceral peel, be excised. Only in this way can the thorax be freed from its inner dense fibrous stricture allowing the ribs and contracted intercostal spaces to resume their motion. It is our opinion that recovery of function following decortication depends in large measure on the completeness of the excision of the entire peel. In this we are in agreement with Gale,[8] who feels that it is essential to excise the parietal encasement to achieve functional recovery. Tuttle,[16] on the other hand, more concerned with obliterating the empyema space, has followed the original procedure, excising only the visceral peel.

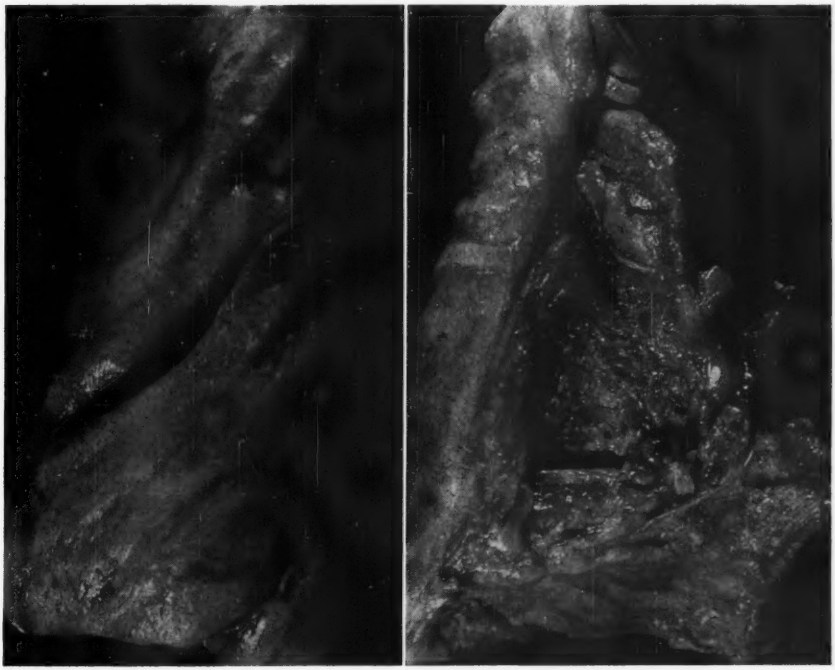
In placing the thoracotomy incision for excision of a complete empyema it is well to follow the area of the sixth or seventh interspaces in order, by low thoracotomy, to allow as ready access to the diaphragm as is consistent with exposure of the thoracic vault as well. Localized collections may demand specially placed incisions, but it is well to remember that the diaphragm is frequently more markedly involved than the preoperative x-rays may make it seem. Dissection of the parietal peel must be carried out through the endothoracic fascial plane. In most cases in which the peel is thick, dense, and fibrous, it is impossible to excise the pleural sac intact. The empyema cavity is entered, evacuated, and an incision made through the visceral peel down to the pleura. It is, surprisingly enough, the rule to find the visceral pleura intact, except in those areas where the presence of a small caseous tubercle may represent the source of the initial inoculation of the pleural space at the inception of the effusion. Gentle, blunt and sharp dissection frees the lung from the peel once a proper line of cleavage is found and maintained. Small tears into superficial lung parenchyma seal readily on later expansion of the lung to meet the parietes. Rapid obliteration of the pleural space and antibiotic therapy combine to prevent the re-formation of a pleural accumulation inoculated with viable tubercle bacilli.

The vascularity of the peel varies with its age and the activity of the inflammatory process. Bleeding tends to be more brisk from the inner surface of the thoracic wall and the diaphragm than from the lung surface. Blood loss is expected to be great and should be measured and replaced volume for volume. In 7 patients, operated upon within six months of their initial effusion, the blood loss averaged 1,500 c.c. Eight patients, with an interval greater than six months, averaged a blood loss of 560 c.c. These figures indicate the peel maturity and well-defined plane of separation in those peels that are more mature and fibrotic.

In certain instances, in which the caseous tuberculosis of the thick, fibrous peel over the diaphragm has made its separation from the superior surface of the diaphragm impossible, we have been forced to excise portions of the

diaphragm down to the underlying peritoneum. On the right, the subjacent liver makes this procedure more acceptable than on the left where careful reconstruction of the diaphragm has been necessary to prevent herniation. In any case, we have felt that excision of the caseous tuberculosis of the peel must be complete to prevent re-establishment of the tuberculous empyema. This may be technically taxing.

Re-expansion of the freed lung in the postoperative period may be slow. Air leakage from raw lung parenchyma is inevitable. To aid expansion we have placed tubes at base and apex to which negative pressure has been applied. To counteract marked leakage of air, the Chamberlain pump has been used. Meticulous care that all fluid and air collections are evacuated as rapidly as possible is essential to success.



A. *B.*

Fig. 2.—*A*, Parietal "external" surface of 25 by 20 by 4.5 cm. peel. Note rib notching. *B*, Visceral "internal" surface. J. T., 21-year-old woman, operated upon two months following diagnosis of tuberculous pleurisy with effusion. The result was excellent (see Table I). The specimen showed grade 2 activity of tuberculosis.

Ten specimens of resected peel were measured and averaged 22 by 17.7 by 4.3 cm., or 1,683 c.c. Except in peels less than six months of age, the size had little bearing on blood loss. Most of the peel specimens were involved in an active tuberculous pleuritis with either caseous nodules, fibrocaseous foci, or simple tubercles of various histologic grades. Eight specimens had definite

loculations and cavities ranging in size from 10 c.c. of content to one containing 500 c.c. of purulent material. The two extremes can be seen in the accompanying photographs. The first (Fig. 2, *A* and *B*), a completely organized fibrous peel, collapsed the left lung and produced a completely nonfunctioning lung in spite of normal parenchyma. The second (Fig. 3), though not handicapping function, represents a residual pleural caseous nodule following resolution of the initial pleural effusion.

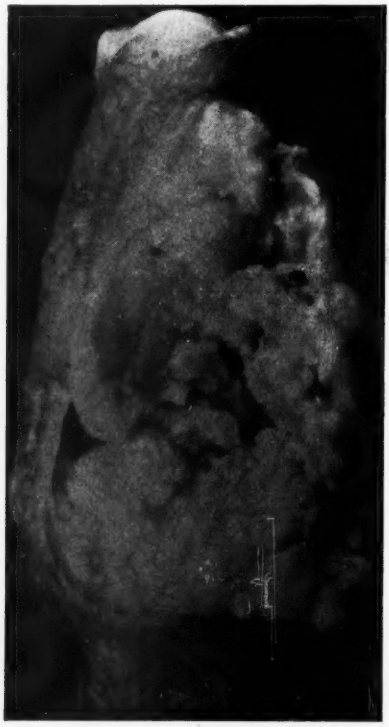


Fig. 3.—Cross section of caseous nodule 7 by 2 by 1.5 cm. K. M., 19-year-old girl, operated upon two years and eight months following effusion onset. Classified as "tuberculous empyema," grade 1 plus activity of tuberculosis.

Postoperative Function Results.—The literature holds a paucity of pre- and postoperative function studies, particularly bronchospirometric determinations with reference to this problem. Gaensler's work has shown us that bronchospirometric and oxygen uptake determinations are the only accurate method in assessing reduction of lung function since cortication may not change ventilation or reduce vital capacity appreciably.[7] The 4 cases of Falk and his co-workers appear to be the largest series reported.[6] On evaluating their pre- and postoperative figures in the effusion-decortication group, they found that the improvement in oxygen uptake lies in the same range as the inexpansible lung (pneumothorax)—decortication group, namely around 8 to 10 per cent. It was their feeling that

results were poorer in tuberculous decortications than in nontuberculous decortications due to the inherent tissue changes of tuberculous pleuropulmonary disease. Since the inexpansible lung and posttherapeutic pneumothorax empyema often represent extensive underlying parenchymal disease with a superimposed pleural cortication, we believe the results can not be truly comparable. Carrol, McClemont, Himmelstein, and Cournand, reporting postoperative function studies on 3 patients with tuberculous pleural disease treated with decortication, were among the first to show significant improvement in function

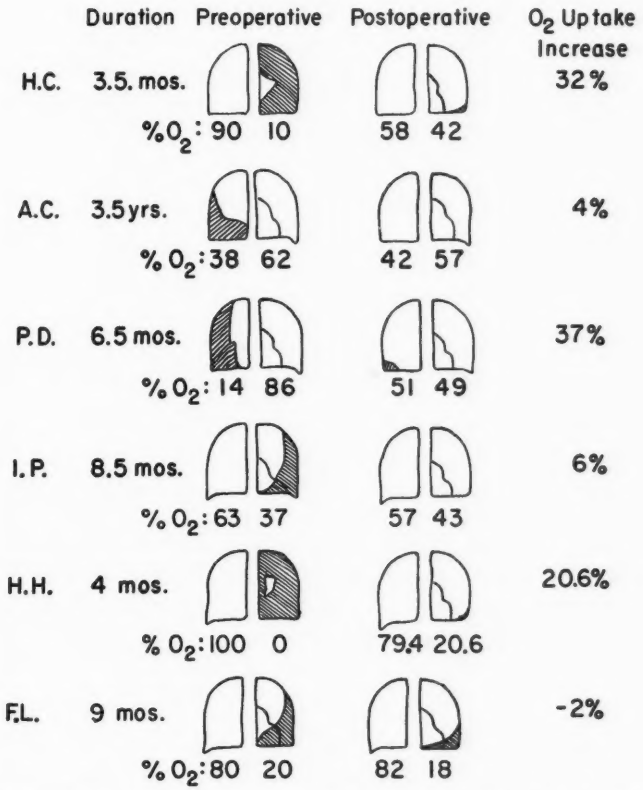


Fig. 4.—Composite drawings of preoperative and postoperative x-rays with bronchospirometric function valves (oxygen uptake per cent) of 6 patients with tuberculous pleuritis.

(oxygen consumption) in those cases with little to no demonstrable parenchymal disease and with pleural disease of short duration.[3] Patton, Watson, and Gaensler state clearly that restoration of function after decortication is closely related to the presence or absence of pre-existing parenchymal disease.[13]

Table II details the total function studies obtained in 6 of the 16 cases reported, and Fig. 4 briefly summarizes the correlation of these results with the x-ray findings (schemogram) and duration.

TABLE II. PULMONARY FUNCTION STUDIES IN 6 PATIENTS BEFORE AND AFTER DECORTICATION FOR TUBERCULOUS PLEURITIS

	PREOPERATIVE STUDIES								POSTOPERATIVE STUDIES*							
	LUNG FUNCTION				BRONCHOSPIROMETRY				LUNG FUNCTION				BRONCHOSPIROMETRY			
					UPTAKE O_2 PER CENT		VENTILATION O_2 PER CENT						UPTAKE O_2 PER CENT		VENTILATION O_2 PER CENT	
PATIENT	PREDICTED MBC	OBS.† MBC	PREDICTED PER CENT	VC PER CENT	R	L	R	L	PREDICTED MBC	OBS.† MBC	PREDICTED PER CENT	VC PER CENT	R	L	R	L
H. C.	135.5	78.7	58.0	55.4	90	10	96	4	140	93	66.0	61	58.0	42.0	53.0	47.0
A. C.	127.0	93.5	73.5	53.0	38	62	42	58	122	96	78.5	54	42.0	57.0	48.5	51.5
P. D.	100.0	76.0	76.0	51.0	14	86	39	61	99	85	86.0	63	51.0	49.0	51.0	49 0
I. P.	96.0	91.0	94.0	86.0	63	37	62	39	97	94	97.0	94	57.0	43.0	54.0	46.0
A. H.	141.0	105.0	74.0	45.0	100	0	100	0	141	135	95.0	60	79.4	20.6	72.0	28.0
F. L.	99.0	76.0	76.5	45.0	80	20	74	26	---	---	---	--	82.0	18.0	76.0	24.0

*All postoperative studies carried out six to seven months following decortication.
†OBS = Observed.

Three of these patients (H. D., P. D., and H. H.) showed striking improvement in oxygen consumption after decortication. The duration of their disease before surgery was less than seven, three and one half, six and one half, and four months, respectively. All, initially, had less than 15 per cent oxygen uptake on the involved side. Of the remaining 3, A. C. and I. P. had excellent x-ray improvement but negligible improvement in oxygen uptake. The preoperative levels of 2 patients, however, were not markedly depressed, being 38 per cent and 37 per cent, respectively. The last patient, F. L., showed gradual improvement over a two-year period in x-ray films but revealed no significant degree of oxygen uptake percentage increase. Severe postoperative hemothorax undoubtedly contributed to his failure to improve functionally. Of all the 6 patients studied in this fashion, those 3 who derived x-ray and function recovery had, by sputa and tomographic study, the least degree of intrinsic pulmonary tuberculous disease. We wish to emphasize the point again that it is in this group of patients that decortication for tuberculous pleural disease will accomplish the most significant degree of functional improvement.

DISCUSSION

Decortication of an active tuberculous peel and empyema is important in the total rehabilitation of patients with unresolved or organized tuberculous pleuritis. Its role is dependent upon the unsuccessful re-expansion of the involved lung or unsuccessful ablation of the constricting peel by other conservative measures. Serous pleural effusions, with or without positive tuberculous organisms, will often be followed by the development of a fibrotic pleural peel, the ideal surgical maturity of which is probably two to four months. Unaspirable fluid with x-ray evidence of residual pleural opacification heralds the build-up of this peel. Disregarding functional disability, slow and protracted improvement in x-rays would be expected. When time and function are important as in this problem, decortication of the peel should be considered. Mixed empyemas, on the other hand, are dependent on the presence of an open bronchopleural fistula. Such fistulas, in our experience, cannot often be closed successfully without resection of the portion of lung from which the fistula originates, which usually demands pleuropneumonectomy. Mixed empyema is therefore, in most instances, a contraindication to an attempt at decortication.

One expects, depending on the size of the peel, reduction in total lung function. We concern ourselves with reduction in oxygen consumption (milliliters of oxygen removed by pulmonary capillary blood flow), believing this to be a more definite criterion of absolute function than the MBC (maximum breathing capacity) and VC (vital capacity) determinations so often performed in these cases. The oxygen uptake or consumption reflects the volume of pulmonary capillary blood flow and the amount of oxygen in the incoming venous blood, the latter generally constant for age, size, etc., if the metabolic rate of tissues for oxygen is not increased. The maximum breathing capacity and vital capacity studies in the presence of almost complete hemipleural

obliteration may erroneously show near normal function since ventilation may be maintained. Though the pliancy of lung tissue is reduced by the pleural peel this single factor may be overcompensated by muscular force and rate increase in the presence of a clear and free airway. Despite maintenance of ventilation, circulatory perfusion, as evidenced by oxygen uptake studies, may be markedly reduced. This is accounted for by reduced pulmonary capillary flow, second to increased peripheral resistance, known to occur in compressed lung.[4, 13] Generally, however, both ventilation and perfusion studies are equally reduced with encasement of a lung.

We feel justified by this experience in challenging such statements as "decortication in pulmonary tuberculosis does not offer the degree of improvement in pulmonary function often noted after decortication in nontuberculous disease and should not be the primary object of such therapy in tuberculosis."[18] True, the excision of the empyema is most often the consideration of first importance. But if the effusion which is no longer aspirable is attacked early, gratifying return of function to normal or near normal levels may result.

SUMMARY

1. An analysis of 16 cases of organized tuberculous pleuritis treated by visceroparietal decortication is presented. Of the 16 cases, six preoperative bronchospirometric determinations are included with accent on comparative oxygen uptake studies.

2. Certain technical points are stressed for maximum operative achievement. Parietal pleurectomy to accompany visceral pleural ablation is strongly urged.

3. Decortication as a primary operation for tuberculous pleural disease in the presence of minimal parenchymatous involvement is generally safe and is not associated with appreciable mortality and prolonged morbidity. When bronchospirometric studies of the involved side disclose reduction in oxygen uptake to levels below 15 to 20 per cent and the duration of the disease is short, one can expect return of ventilatory and circulatory function to normal or near normal levels.

We wish to thank Dr. James Martin, head of the Pulmonary Physiology Laboratory at Firland Sanatorium, for his bronchospirometry data used in this report.

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THE ARTERIAL DISTRIBUTION TO THE LEFT UPPER PULMONARY LOBE

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THE discrepancy noted between our experience with the arterial supply of the left upper lobe and that described in the literature has prompted us to record the patterns which we have encountered. As so frequently happens in medicine, an original misconception, often reiterated, and accepted uncritically attains all the validity of an established fact.

We are particularly concerned with the obviously erroneous conception that the first branch of the left pulmonary artery is an apical or apicoposterior vessel rather than an anterior or apicoanterior trunk. The concept that the lingular artery is very frequently the source of at least a part if not the major arterial supply of the anterior segment is also considered unrealistic.

As nearly as can be determined, Kent and Blades[1] in 1942 made the first attempt to advance the knowledge of the arterial anatomy of this area beyond the meager descriptions of the Gray, Cunningham, and Spalteholz texts. They described the course of the left main pulmonary artery and found that it gave off from 4 to 7 short trunks which supplied the upper lobe.

In 1944, Appleton[2] described the anatomic distribution of the blood vessels as gathered from the study of the dissections of 50 right and 50 left lungs. His description of the left pulmonary artery states, "this artery in arching over the left upper lobe bronchus provides arteries for the apical and posterior bronchi. Now the artery for the pectoral segment bronchus occasionally arises anteriorly before the arch; more often it arises afterwards, and it is then below the origin of the artery of the dorsal segment of the lower lobe. The lingular artery usually arises after the main artery has arched over the bronchus; it then passes forward below the bronchus." The statement referable to the anterior (pectoral segment) artery arising after the posterior artery is definitely incorrect yet has been repeated again and again in subsequent texts by various authors.

In 1945, Boyden[3] wrote on the intrahilar and related segmental anatomy of the lung based on the dissection of two pairs of lungs. He stated, "The first branch of the left pulmonary artery is an apicoposterior trunk (the apical of Herrnheiser and Kubat, or ascendens of Melnikoff). It arises on the convex superior surface of the pulmonary artery and, according to Melnikoff, is most commonly a sessile trunk which divides immediately into apical and posterior segmental arteries." In his figures, Boyden showed the anterior artery arising

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from the lingular trunk and it was so described in the text along with another variation which depicted the anterior artery as a branch from a common anterior-apico-posterior trunk.

In 1946, Boyden[4] reported a more extensive analysis of the variations in the left upper lobes of 50 lungs. This study is essentially in rather close agreement with our own conclusions. He found that the number of arteries to the upper lobe varied from 4 to 8 with a mean number of 5.4. In only 14 per cent of the cases did he find even part of the anterior segment supply arising from the lingular artery. In only 22 per cent of the specimens did he find a common apicoposterior segmental artery. He stated, "Of special interest is that the apical and posterior vessels arise independently of each other in more than ¾ of specimens notwithstanding the fact that the corresponding bronchi arise in 78 per cent of specimens from a common stem."

Sweet,[5] in his text in 1950, described the left pulmonary artery as follows: "The artery arches upwards, inclining posterolaterally above the bronchus. At this point it usually gives off its first upper lobe branch which is distributed to the apical and posterior segments. . . . The main vessel rises over and curves behind the upper lobe bronchus. Along this curved portion it gives off one or more branches to the apical, posterior and anterior segments." In Fig. 87, page 162, in the illustration of a left upper lobectomy, the first and second branches are separate apical and posterior arteries while the third vessel is the anterior and the fourth is the lingular artery. In contrast, however, Fig. 15, page 32, a colored three-dimensional diagram of the left upper lobe segments, depicts the first artery going to the anterior segment, the second to the apical, the third to the posterior, and the fourth to the lingular segment. This latter description is essentially the arrangement we have found.

Overholt and Langer[6] in the revised 1951 edition of their text describe the arteries to the left upper lobe as follows: "We have found them most frequently from four to six in number arising from the pulmonary artery independently as short stems. At other times the segmental arteries have been found to have common trunks. The apico-posterior trunk has two branches for the apical posterior bronchus, and the anterolingular trunk has three branches, one for the anterior segmental bronchus and two for the lower division of the left upper lobe branchus (lingula). . . . The anterior segmental artery arises in the interlobar portion of the pulmonary artery as a branch of the anterolingular arterial trunk or independently from the main artery." Notwithstanding the above description, the colored diagram, Fig. 27, page 90, is said to illustrate "the most common arterial pattern." It shows two branches to the upper lobe, the first is an apicoposterior trunk while the second is a large anterolingular trunk. Again, in a description of the technique of left upper lobectomy, page 127, Overholt states that "the apical-posterior arteries are the uppermost branches of the pulmonary artery."

Johnson and Kirby,[7] in their 1952 text, state on page 143, "The first branch, the apical posterior trunk, usually arises just as the main artery begins its posterior inferior curve and subdivides into the apical and posterior segmental arteries. It is not uncommon for the apical and posterior arteries

to arise separately. The next branch is the anterior segmental artery which arises most commonly from the anteromedial surface of the main trunk within the fissure. Two variations of the anterior artery are frequently encountered. It may arise as the first branch of the main pulmonary artery anteriorly, in the primary hilum, or from the lingular arteries." Their anatomic plates show the first branch to be an apicoposterior trunk, the second to be to the anterior segment, and the third as the lingular artery. This same pattern is depicted in plates illustrating a left upper lobectomy.

Lindskog and Liebow,[8] in their 1953 text, quote from Boyden's[4] 1946 article.

METHOD OF STUDY

In an attempt to verify our impression, a set of special study sheets were placed in use early in 1952. Each left upper lobectomy or multiple segmental resection of the left upper lobe performed at Herman Kiefer Hospital was charted immediately after surgery as to the distribution of the arteries. As a teaching procedure for the resident staff, each arterial stem was traced to its first major branching and the destination of these branches determined. Those segmental operations were excluded in which calcification and scarring would have rendered hazardous dissection of vessels other than those which required ligation for the proposed operation. No attempt was made to subdivide the individual pulmonary segment or the arteries thereto. While the identification of the secondary and tertiary branches of the segmental arteries is a delight to the anatomist, it has relatively little surgical importance. The subsegmental resection may readily be accomplished by dissection of the subsegmental bronchus following which the accompanying vessels may be ligated as encountered without the necessity of prior identification. The present report is based on 100 cases where the entire arterial supply to the left upper lobe could be clearly identified and traced.

RESULTS OF THE STUDY

From Table I it is evident that in 87 per cent of the cases there will be 3, 4, or 5 arteries with the greatest number of patients having 4 arteries.

TABLE I. NUMBER OF ARTERIAL BRANCHES TO THE LEFT UPPER LOBE

NUMBER OF BRANCHES	NUMBER OF CASES AND PER CENT
2	5
3	31
4	41
5	15
6	7
7	1
	100%
Mean 3.9	

The illustrations are more or less self-explanatory. From Fig. 1 it is quite obvious that the first branch is not an apical, a posterior, or an apicoposterior vessel. In 80 per cent of the cases it is either an anterior, or an apicoanterior branch. Fig. 2 reveals that in less than 10 per cent of the cases does the anterior segment receive more than one artery. Figs. 3, 4, and 5 reveal

that the arterial supply to the apicoposterior segments is varied indeed although in over one half of the cases there will be one of four dominant patterns. In the remaining 43 per cent, however, there will be eighteen separate and distinct patterns of vascularization.

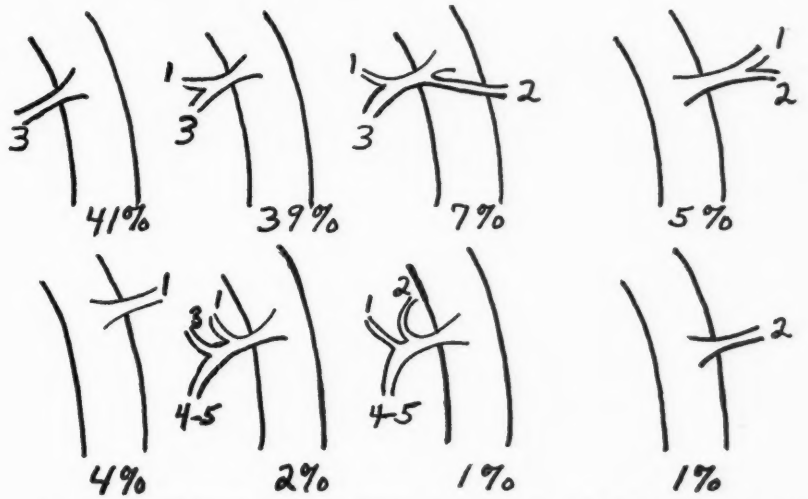

Fig. 1.—The first branch of the left pulmonary artery. In all Figures the Jackson-Huber classification is used with *1*, representing the apical; *2*, the posterior; *3*, the anterior; and *4-5*, the lingular segmental arteries. It will be noted that in 80 per cent of the specimens the first branch is either an anterior or apicoanterior artery. By contrast, in only 10 per cent is the first branch an apical, posterior, or apicoposterior artery.

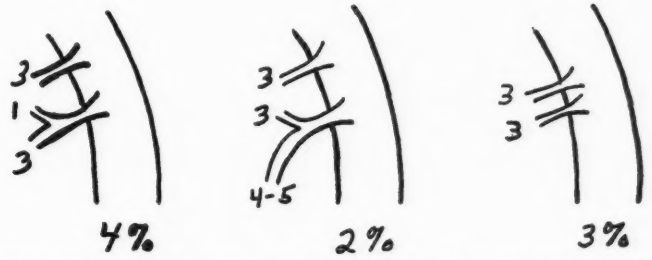

Fig. 2.—Multiple arteries to the anterior segment. In 9 per cent of specimens, the anterior segment is supplied by two arteries. In 2 per cent, this auxiliary supply is derived from the lingular artery. Reference to Fig. 7 will show that in a total of 8 per cent *an* anterior artery arises from the lingular branch. Thus in only 8 per cent of the specimens is either the total or partial blood supply to the anterior segment derived from the lingular artery.

TABLE II. NUMBER OF LINGULAR ARTERIAL BRANCHES

One Artery	89 per cent
Two Arteries	10 per cent
Three Arteries	1 per cent
	100 per cent

Table II illustrates that in the great majority of cases there is a single artery to the lingular segment.

Fig. 6 reveals that in two thirds of the cases, the lingular artery or arteries arise at or below the level of origin of the superior segmental artery. Thus in two thirds of the cases, when performing lower lobectomy, it would be

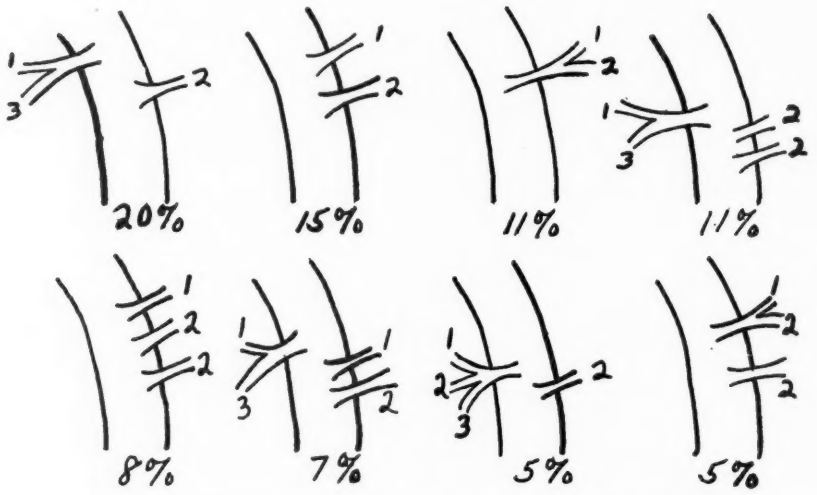

Fig. 3.—The more common arterial distributions to the apicoposterior segments. Well over one half of the specimens will have one of the four distributions shown in the top of the figure. In only 26 per cent (15 per cent + 11 per cent) are these segments supplied solely by a common trunk or by two separate trunks.

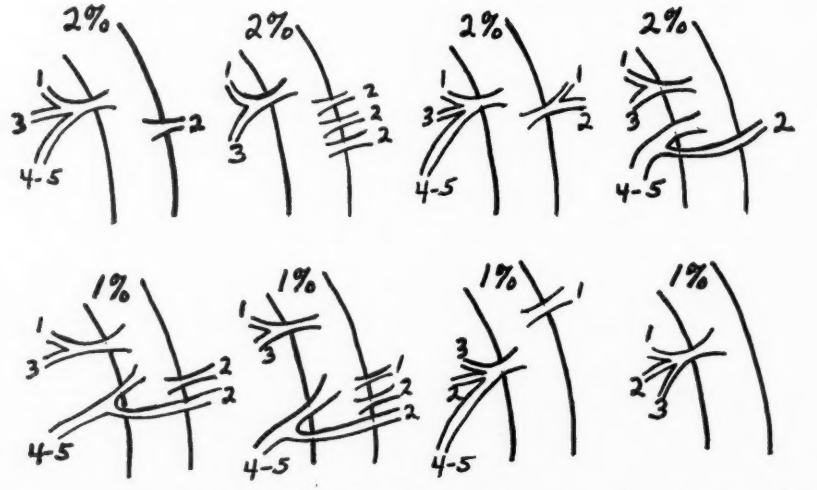

Fig. 4.—Less common arterial distributions to the apicoposterior segments. From Figs. 3, 4, and 5, it is obvious that the vessel pattern to the apicoposterior segments is the most varied of all the segments.

necessary to ligate the superior segmental artery separately and then ligate the main arterial trunk below the origin of the lingular vessels. This, of course, is in agreement with the experience of most observers.

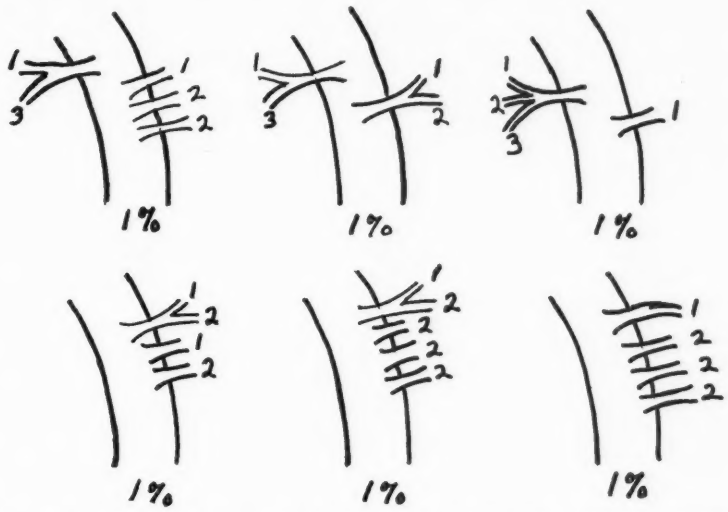

Fig. 5.—Least common arterial distributions to the apicoposterior segments. Reference to Figs. 4 and 5 will reveal that in one fifth of the specimens, fourteen separate and distinct patterns were noted.

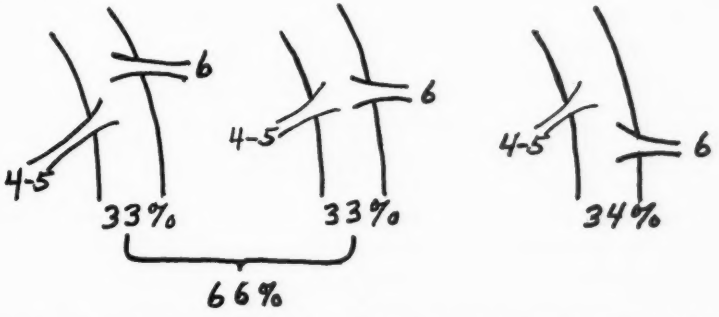

Fig. 6.—Comparative levels of origin of the lingular and superior segmental (segment 6) arteries. It will be noted that in two thirds of the cases, the lingular artery arises at or below the level of origin of the superior segmental artery. Thus, in only one third of cases, while doing a lower lobectomy, would it be feasible to do a single mass ligation of the arterial supply to the lower lobe.

Fig. 7 demonstrates that in approximately one sixth of the cases only does the lingular artery or arteries supply segments other than the lingula. In only 8 per cent of the cases will the anterior segment receive even part of its supply from the lingular vessels. In 4 per cent the lingular artery sends a branch to one of the basilar segments of the lower lobe. Fig. 8 represents the most common single pattern encountered.

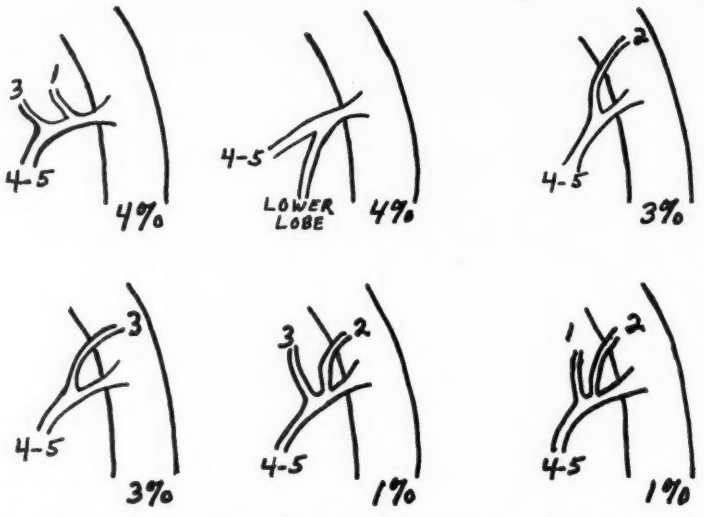

Fig. 7.—Less common lingular artery patterns. Table II has shown the variation in number of the arteries supplying the lingula. This figure shows that in 16 per cent of specimens, the lingular artery or arteries supply segments other than the lingula.

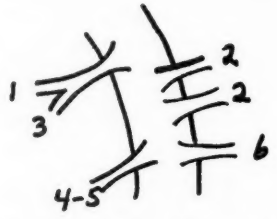

Fig. 8.—The most common single arterial pattern.

CONCLUSIONS AND SUMMARY

It has been our purpose in this report to clarify the arterial anatomy of the left upper pulmonary lobe and to correct some misconceptions which have gained wide acceptance through sheer repetition. Whereas it has been stated that the first branch of the left pulmonary artery is most frequently an apicoposterior trunk, we have found in a study of 100 cases that this occurs in only 10 per cent. Conversely, the first branch has been found to be an anterior or apicoanterior artery in fully 80 per cent of the cases. We have not found the lingular artery to be a significant source of supply to the anterior segment. A considerably larger unrecorded experience has shown no major divergence from these findings.

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RECONSTITUTION OF THE LUNG

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THE concept that once the lung has been incised, or a section of tissue has been excised, the remaining raw surfaces cannot or should not be reapproximated, is open to challenge.

Kausel and Lindskog[1] state that most observers have been in agreement with Clagett and Deterling, who are quoted as believing that the raw surface of the lung should not be closed by suture, feeling that such a technique predisposes to obstruction, possible bronchiectasis, and unnecessary loss of lung parenchyma. Reference to the article of Clagett and Deterling[2] does not furnish such a conclusion. Rather, by description and diagram, they illustrate the use of interrupted catgut sutures to approximate the visceral pleura along the line of cleavage (following lingulectomy). Their conclusion being "that as a result of the partial approximation of raw surfaces, the oozing of blood and the danger of poor expansion of pulmonary tissue are further minimized."

The various objections, which have been raised to the reapproximation of raw lung surfaces, may be summarized.

1. There may be some interference with the degree of aeration along the line of resection, where it is particularly vital.

2. Excessive suture material is necessary, which increases foreign body reaction and predisposes to secondary infection.

3. Puckering and reduction in size of the remaining segments are produced: Re-expansion places tension on sutured lung edges, and disruption of the suture level may take place.

4. Over-all re-expansion of the lobe and occupation of residual space in the hemithorax are prevented.

5. Bronchial distortion is produced, which may result in linear or partial segmental atelectasis and predispose to late bronchiectasis.

The question is proper: Why is any reapproximation of raw lung surfaces necessary? A layer of fibrous and areolar connective tissue (reconstituted pleura?) has been shown both experimentally and clinically to regenerate over raw pulmonary tissue.[1]

Although Chamberlain[3] has concluded that the morbidity following segmental resection is no greater than in lobectomy, several reports[4, 11] in the past five years list an appreciably higher incidence of minor "benign" complications, when comparing segmental resection with lobectomy.

By far, the leading complication has been the persistence of so-called "air leaks." At what point these leaks become bronchopleural fistulas is not clear. We have tried to define a fistula as clinically significant when it requires any

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more than ordinary postoperative care, or unduly prolongs operative convalescence. Thus, prolonged intubation or the necessity of a postresection thoracoplasty would seem to indicate the presence of more than a simple air leak.

The persistence of small bronchopleural fistulas, when segmental resection has been performed for acute or chronic suppurative conditions, is undoubtedly of serious import. The development of local or total empyemas, particularly of the mixed type when the organisms may be drug resistant, constitutes a major problem.

The formation of a postresection space following segmental excision for tuberculosis is, probably, a benign complication when it is considered that the majority of patients who have resection performed today have bacilli which are susceptible to the antitubercuIous drugs. Thus, inadvertent spillage at operation, or subsequent contamination of the pleural space, is readily controlled. In those patients, however, with resistant organisms known or suspected in the sputum or resected tissues, such ineffective drug control may contribute to local reactivation, empyemas, and fistulas.

When a wedge or triangular-shaped defect follows a segmental or deep retrograde wedge resection, the margins of the defect may adhere to the parietal chest wall. Thus, the general pleural space is effectively sealed off, but a pyramidal-shaped space is formed. At the apex is the segmental or subsegmental bronchial stump, the two sides are formed by raw lung surface, while the third boundary is parietal pleura. Another variety of such a pseudocavity results when the tip of the superior segment of the lower lobe forms the outer boundary of a space remaining after excision of the posterior or apical posterior segments of the upper lobe. The prompt infection of such spaces by uncontrolled tubercle bacilli has occurred in 8 of our patients when such resistant organisms in the tissues were unsuspected.[5, 6] In one of these cases, fatal hemorrhage followed erosion into a pulmonary vein three months after bisegmental resection. A pseudocavity, such as described previously, with an occult fistula of the apical posterior bronchial stumps was found at post-mortem examination.

Judging from the variety of methods which have been suggested for repleuralization, thoracic surgeons have not been unconcerned with the problem of the remaining raw lung surface.

Whenever it is possible for the dissecting fingers to remain in the intersegmental plane, bleeding points and air leaks may be kept to a minimum. The proximity of nodular tuberculosis to the segmental plane, and the desire to encompass such disease by a suitable margin, may cause wedging into the adjacent segment, with subsequent increase in air leakage. Good technique requires the surgeon to arrest any bleeding points or significant air leaks on this raw surface before considering approximation of a pleural flap or any similar sealing maneuver. The use of fine No. 3-0 or 4-0 silk or catgut, applied as interrupted or mattress sutures, is adequate in most instances. Some prefer free ligature about the tip of a mosquito forceps or other fine clamps. These details do not seem important if excess suture material and scattered islands of necrotic debris, or devitalized tissue, are avoided.

Review of current thoracic surgical texts offers no unanimity of suggestions for treatment of the raw lung surface remaining after removal of a segment.

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Sweet[7] indicates "it *may be left as it is, accepting the greater probability of air leakage;* otherwise, it can be closed by means of continuous fine catgut sutures, which approximate the edges of the lobe, thus pleuralizing the entire surface. A modification of this method is to preserve a long sheet of pleura from the surface of the segment which is being removed as the dissection is carried out. This sheet of pleura is then turned over the denuded area and held in place by sutures around the periphery. There is *reason to believe that the incidence of complications is considerably reduced by closing the denuded surface of the lung.*" Lindskog[8] describes the fashioning of pleural flaps for coverage of bronchial stumps, but indicates no attempt is made to repleuralize the denuded surface. Overholt[9] believes the use of sutures to effect pleuralization following segmental resection has proved to be disadvantageous. "They are difficult to place without inviting air leakage, and the normal shape of the remaining segments is altered and reduced in volume." Scannell[10] describes closure of the wedge-shaped defect, following anterior segmentectomy in the left upper lobe, by approximating the upper surface of the lingula to the apico posterior segment. Incidentally, this maneuver also covered the bronchial stump with normal lung.

Preservation of a suitable flap or apron of visceral pleura may be dangerous, as well as most difficult in segmental resections for tuberculosis, because of the common subpleural location of nodular lesions. Many surgeons have sporadically attempted to reapproximate the cut margins of visceral pleura. Most of these efforts have been doomed to failure, as the apparent dead space in the defect would fill with blood or serosanguineous effusion. In some cases, infection of this operative site with secondary organisms or tubercle bacilli, and evacuation of its contents into the bronchial tree or pleural space, would *result in a pseudocavity larger than that originally present.*

RECONSTITUTION

Because of the frequent observation that lungs with brisk and prolonged air leakage, following segmental or subsegmental resections, were the slowest to re-expand, and were the greatest contributors to the postresection space problem, it appeared that if one raw surface could be carefully approximated to the other, with obliteration of all dead space, primary healing, resulting in a linear parenchymal scar, could be anticipated.

The reapproximation of raw surfaces following unisegmental, bisegmental, or large wedge excision has now been performed in 75 cases. The term reconstitution of the lung has been used, implying the restoration of the lung parenchyma to as near its former continuity and shape as possible.

The technique is described in the accompanying diagrams. Certain points may be stressed.

1. The wedge or pyramidal-shaped defect is closed from the bottom outward (Fig. 1). The same principle is followed as with soft tissue surgery in general; i.e., careful obliteration of all dead space.

2. It is helpful to have the lung partially inflated during reconstitution. A state of atelectasis or full inflation makes suturing difficult and may result in unnecessary deformity.

3. A traction suture at the apex of the defect aids the tendency of the parenchymal surfaces to fall together.

4. The first or crown stitch, at the level of the bronchus, picks up three points; the lowermost limit of the parenchymal pleural margin across to the

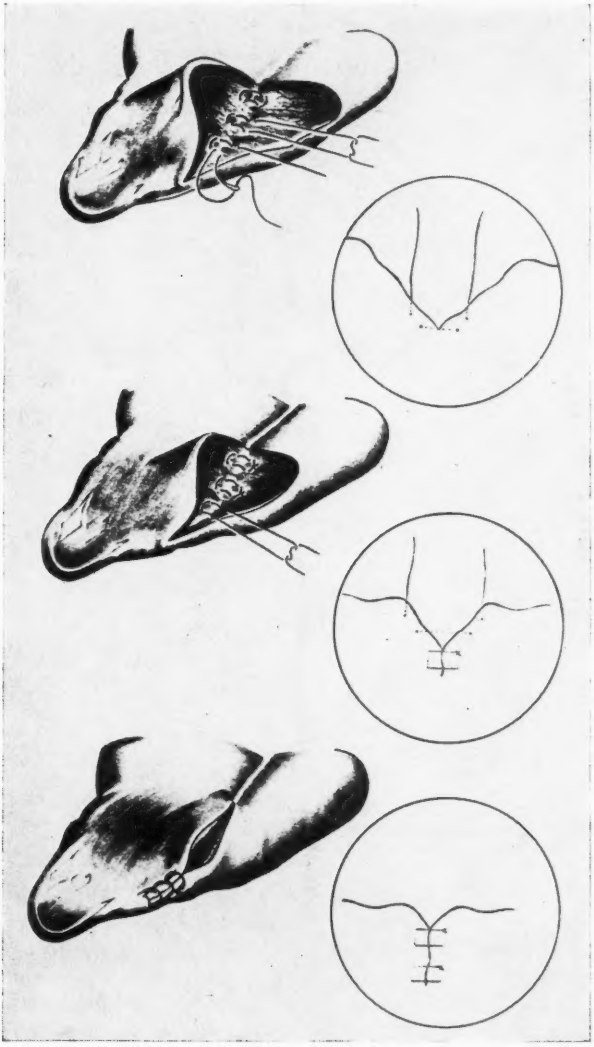

Fig. 1.—Deep wedge resection. *A, B, C,* Successive layers of suturing. Insets: Scheme of closure in cross-section.

outside surface of the bronchus, then across to the opposite edge. This suture buries the segmental bronchial stump beneath normal lung and completely pleuralizes it (Fig. 2). This detail is stressed in all texts describing segmental

resection technique, and we consider it extremely important. The best possible insurance against fistulas of either segmental or lobe bronchus is adjacent lung rising up over the stump and adhering to it.

5. Several sutures are placed as radial horizontal mattress sutures along the base of the defect, at successively more superficial layers, until the margins of the defect are adjacent.

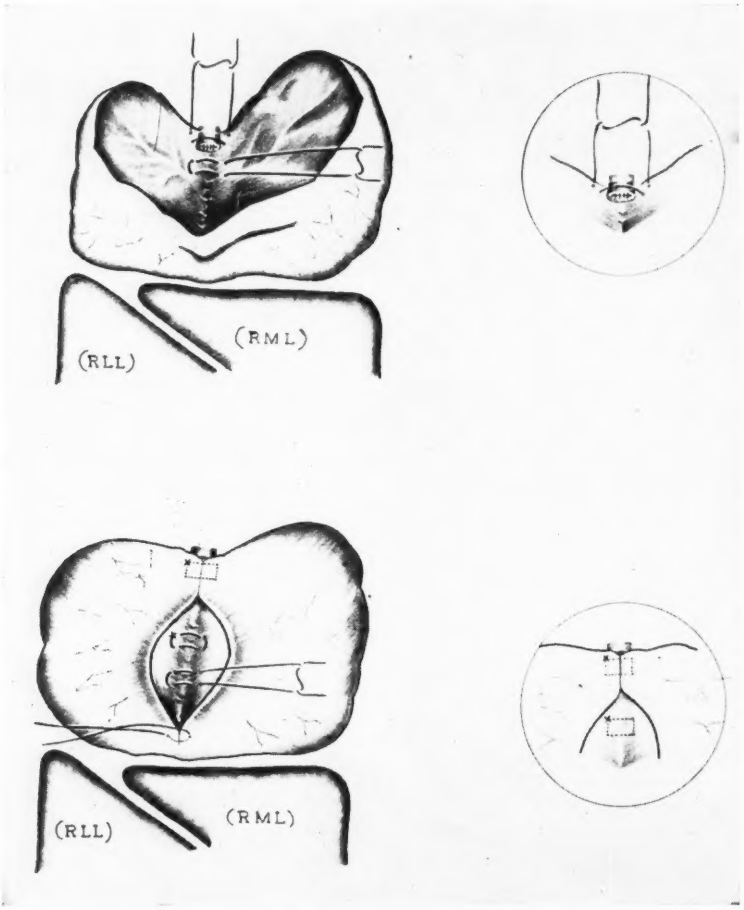

Fig. 2.—Segmental resection (apical). *A*, Beginning of defect closure. Inset: Detail of margin-bronchus-margin suture. *B*, Later stage in closure.

6. It is important that these sutures of either fine catgut or silk, preferably Atraumatic, are placed parallel to the bronchopulmonary ray. This minimizes the chance of transfixing a segmental vein or subsegmental bronchus.

7. If bleeding points and gross air leaks are not controlled before the defect is reconstituted, and further bleeding is caused by poor placement of

sutures, a hematoma may form in the operative site. More likely bleeding will occur into the adjacent lung substance. Several of our earlier cases had distressing hemoptysis for five to seven days postoperatively.

8. Placing a deep suture at right angles to the axis of bronchovascular structures may lead to a complication of this technique. If a particularly large subsegment bronchus is caught in a right angle type suture, an area of parenchyma, distal to this point, may remain unventilated in spite of collateral air drift.

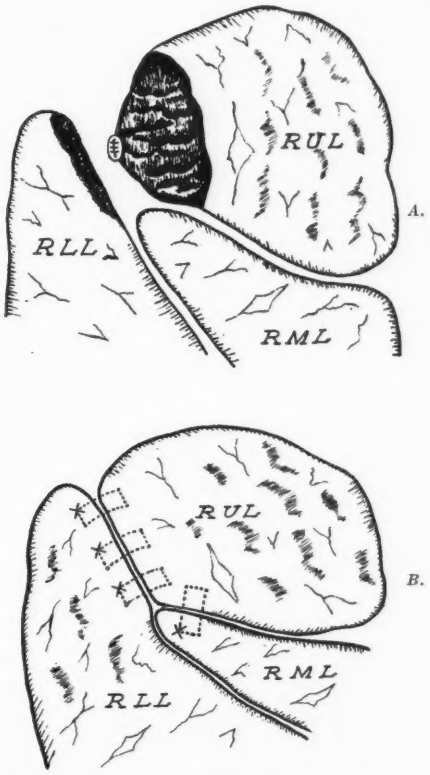

Fig. 3.—Alternate method of reconstitution. *A*, Following posterior segmentectomy. *B*, Use of superior segment, RLL, and medial segment, RML.

This possibility, in addition to any interference with associated blood supply, could result in necrosis and infection of the surgical defect. We have not seen this complication in our material.

SPECIAL SITUATIONS

In addition to the defect following apical or apical-posterior segmental resection in the upper lobe, which lends itself readily to infolding or reapproximation, certain special situations may arise in which the details of the above techniques are not applicable without causing marked deformity.

Following resection of the posterior segment of the upper lobe, or superior segment of the lower lobe, a somewhat irregular but rather flat surface may result, which has no adjacent raw surface for approximation. Local infolding may succeed in almost complete reconstitution. In the event this is unsatisfactory, the adjacent segment may be approximated to the denuded surface of the upper or lower lobe, respectively (Fig. 3). The medial segment of the middle lobe on the right may join into this triangulation effect. If reconstitution of the left upper lobe is not possible after apical-posterior segmental resection, by bringing the usually overexpanded anterior segment to the superior segment of the lingula, the normally high superior segment of the left lower lobe may easily fall against the defect in the upper lobe.

In most cases where anatomically incomplete fissures are divided, the partial or completely raw surface may be reconstituted and repleuralized by gently rolling in one margin toward the other. In lungs with a fibrotic substrate and moderate emphysematous changes, these maneuvers help significantly to reduce postoperative air leakage and contribute to prompt space occupation.

DISCUSSION

Certain factors, peculiar to tuberculosis, have made the application of lung reconstitution more valuable for segmental resection in this disease than, perhaps, in other pulmonary conditions. It is not usually possible or wise to excise tuberculous lesions, or divide incomplete fissures, with a blind clamping and oversewing technique. The danger of crushing and spilling caseous lesions with the clamps, and then burying this tissue in a continuous locked stitch, is a potential hazard. The only manner in which we have been able to accomplish the removal of all or nearly all palpable lesions in tuberculosis is to "feel our way around the disease." A large nodule may abut on the theoretical segmental plane, and the only way to clear it, and possibly a few satellite nodules, is to wedge slightly into the adjacent segment. This would appear difficult with the use of long Kocher or other crushing clamps.

The widespread location of tuberculous lesions throughout the parenchyma, up to and including the subpleural level, makes the dissection of a pleura flap for purposes of raw surface coverage almost impossible. In addition, the operator runs the ever present danger of breaking into underlying disease during such dissection. The viability of such flaps, either free or pedicled, has always been questionable. At times, the use of parietal pleura, as a so-called apical pleural tent, or fashioned in other ways, has proved useful in covering denuded surfaces.

The common observation that segments adjacent to those containing disease have undergone compensatory overexpansion, while their neighbors contracted, was a point in favor of reconstitution.

Taking advantage of the stage which nature has set, the surgeon can restore the continuity of the parenchyma by approximating the large remaining segments at their raw interfaces. In some instances, the walls of the defects appear almost to fall together, with little or no tension on the suture line. The surgeon may criticize himself for deforming the lung, but the disease has preceded him, and he has only to supplement the body's healing efforts by restoring the continuity of the lung whenever possible.

The further criticism has been raised, whenever reapproximation of segmental defects is advocated, of causing bronchial distortion. Since the bronchi are the most inelastic of parenchymal structures, this objection may be valid. However, the following points should be mentioned. As a result of doing routine Dionosil bronchograms, in the group of open-negative patients (sputum

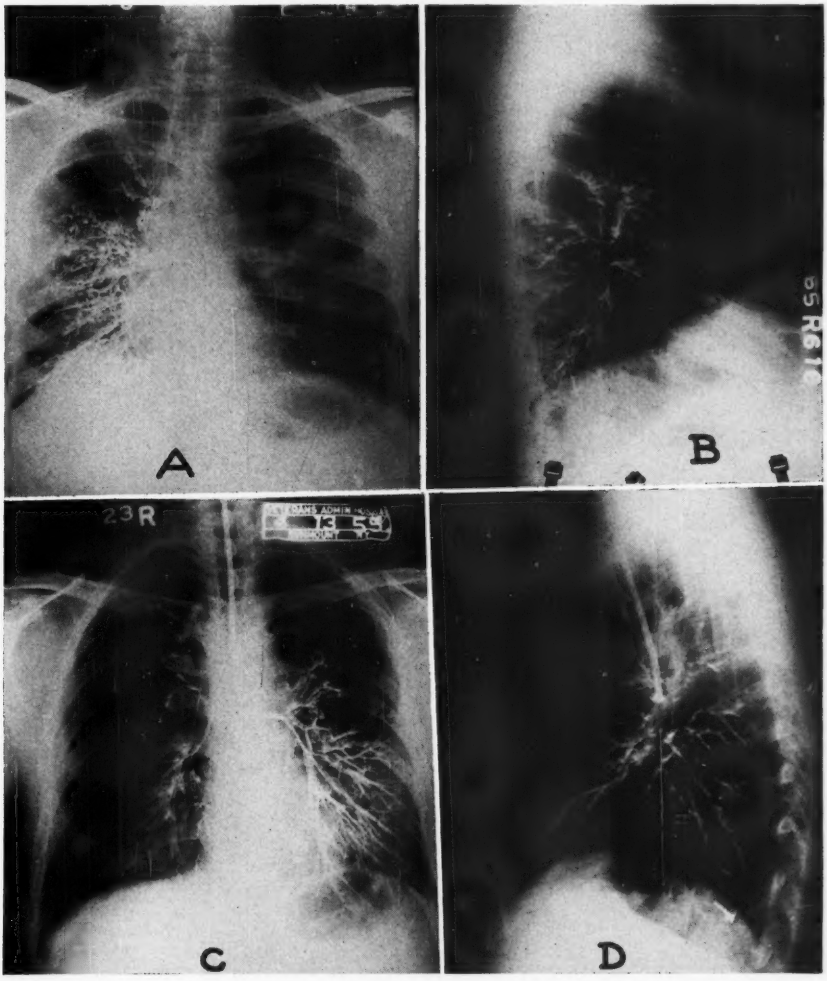

Fig. 4.—*A, B,* Bronchogram six months after apical posterior excision, RUL, and reconstitution. *C, D,* Bronchogram six months after apical posterior excision, LUL, and reconstitution.

negative for three months and residual annular shadows after six to eight months of chemotherapy), in order to delineate the nature of these radiolucencies, we have found minor degrees of bronchial deformity in the majority.. This is not true bronchiectasis. At the same time, it is an *anatomic change as a consequence*

of disease, which does not appear to result in subjective symptoms. Further, the bronchial distortion which is produced by major and minor collapse procedures, used throughout the years for tuberculosis and demonstrable by random bronchograms, is usually asymptomatic.

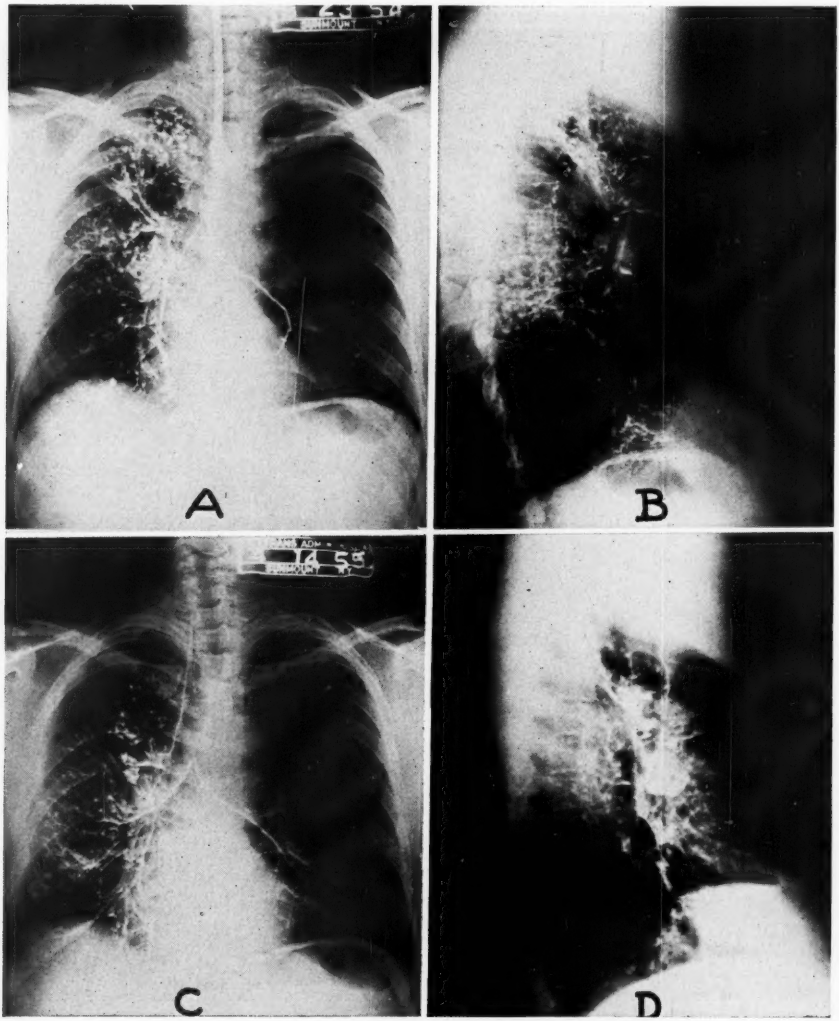

Fig. 5.—*A, B,* Bronchogram preoperation. *C, D,* Bronchogram five months postoperation, apical posterior segment, RUL, and wedge, superior segment, RLL, with reconstitution.

We are not justifying distortion of the bronchial tree by any surgical procedure, since any appreciable deviation from normal must interfere with bronchopulmonary physiology. However, we wish to recall the probability that a great deal of deformity must exist, either as a result of chronic disease processes

or a surgical procedure to treat this disease, that we as physicians are not aware of until the patient's symptoms are sufficient to provoke filling his bronchial tree with contrast media.

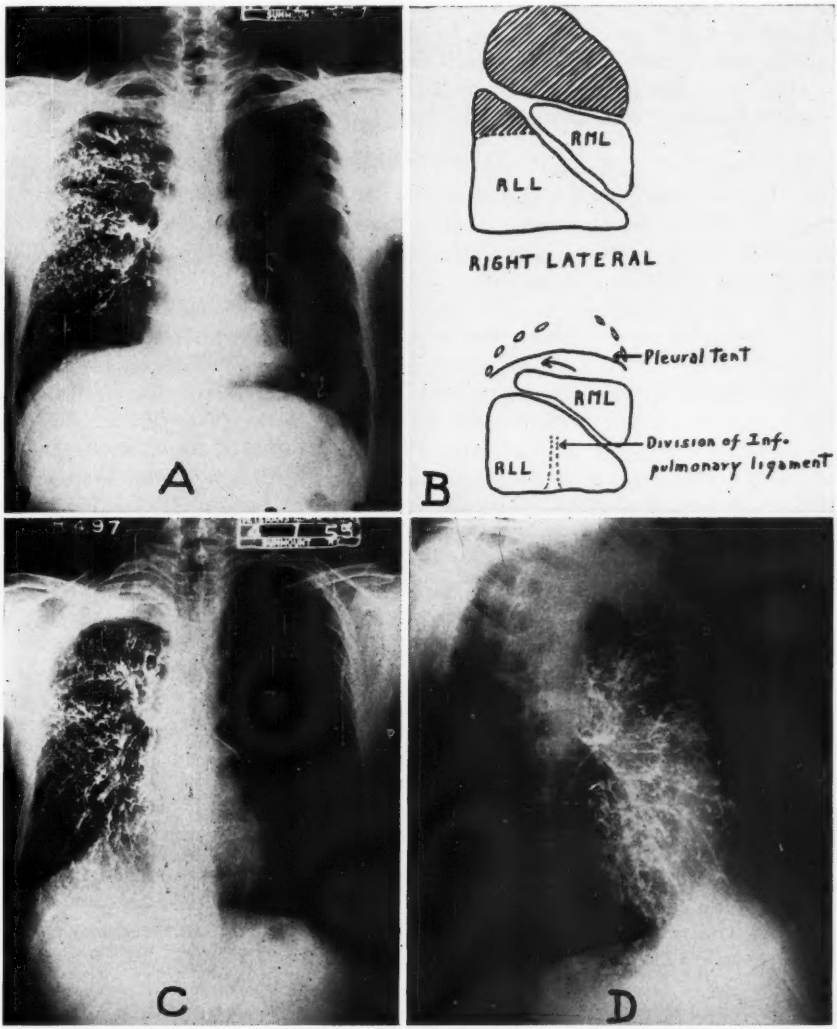

Fig. 6.—*A*, Preoperative bronchogram. *B*, Diagram of reconstitution after RUL lobectomy, and superior segmentectomy, RLL. *C*, *D*, Bronchogram six months postoperation.

Following reconstitution, we have repeatedly observed prompt inflation of the remaining segments, up to the suture margin, without any evidence of trapping or delay in emptying. These findings, plus the absence of any significant deformity in postoperative bronchograms (Figs. 4, 5, and 6) suggest that re-

constitution in most instances does not contribute to or cause bronchial deformity, at least beyond the ability of the bronchovascular structures to undergo some readjustment.

The benign postoperative course which these patients exhibit is a welcome change to the problem of treating bronchopleural fistulas. Many do not leak air for more than one or two hours, if at all. A former incidence of air leakage and postresection space problems in 20 per cent of our patients, who had segmental resections to October, 1954, has disappeared completely.[11]

SUMMARY

1. The technique of reconstitution of the lung following bisegmental, unisegmental, or deep wedge resection is not presented as an original method. We are sure that varieties of raw surface approximation have been and are being used daily by thoracic surgeons.[4]

2. Our purpose has been to stress the details of the method, as we have used it, with particular application to the problem of segmental resection in tuberculosis.

3. The dangers of allowing a large, triangular-shaped, raw surfaced defect to replace itself in the hemithorax may be significant in a patient with resistant tubercle bacilli in the tissues. The possibilities of formation of an infected pseudocavity or operative defect, bounded entirely by parenchyma or by lung and parietal chest wall, are described.

4. The theoretical objections to reconstitution of the lung are discussed. Practically, the results, both at operation and during the postoperative period, are most satisfactory.*

The author is indebted to Mr. John Zagurski for his invaluable help with the drawings, and to Dr. Charles Pierson for assistance with the pre- and postoperative bronchograms.

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*A 16 mm. movie of "The Technique of Reconstitution of the Lung" is available upon request.

CONGENITAL ATRESIA OF THE ESOPHAGUS IN BROTHERS

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THE discovery of congenital atresia of the esophagus in two brothers has prompted a search for instances of similar esophageal defects occurring more than once in one family. The possibility that two children in the same family might be born with atresia of the esophagus has not been seriously considered, since the presumed incidence of esophageal atresia is only one in approximately 3,100 births.

In 1880, MacKenzie[1] reported having seen a male infant who died with atresia of the esophagus. The infant's father stated that a former wife had given birth to an infant who died nineteen days after birth with the same symptoms as those recorded in the present infant. Herzfeld,[2] in 1926, reported the presence of esophageal atresia with tracheoesophageal fistula on autopsy of an infant who was unable to swallow and died six days after birth. A sibling, the first child of the same parents, had died forty-eight hours after birth with similar symptoms. Herzfeld presumed the infants had similar lesions, although an autopsy was not allowed on the sibling.

In 1939, Grieve and McDermott[3] reported the occurrence of congenital atresia of the esophagus in two successive male births in the same family. The mother and father were third cousins. The first boy, born in July, 1937, died shortly after birth and was found to have an esophageal atresia with tracheoesophageal fistula. In July, 1938, the mother gave birth to another son with esophageal atresia and tracheoesophageal fistula. In addition, this child had an imperforate anus. The second child died six days after birth. No operation was attempted for either infant.

Lanman,[4] in 1940, reported the occurrence of congenital atresia of the esophagus with tracheoesophageal fistula in two successive births in the same family. The first patient, a boy, was admitted Dec. 2, 1932, at the age of seven hours because of an imperforate anus. As the blind end was too high to reach from a perineal incision, a sigmoidostomy was done on December third. On the following day, roentgen studies showed complete obstruction of the upper segment of the esophagus and a large amount of gas in the stomach and intestines. On exposure of the posterior mediastinum, an esophageal atresia with tracheoesophageal fistula was found, but the patient died on the table. In December, 1933, the next child, a girl, of the same parents was admitted at the age of two days with an esophageal atresia with tracheoesophageal fistula. At operation the fistula was doubly ligated and divided between the ligatures. The lower

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segment of the esophagus was brought out through the wound, a catheter was inserted and the esophagus was sutured to the skin. The patient died eight hours after operation. An autopsy was not obtained in either case.

Copleman, Cannata, and London[5] reported the occurrence of congenital atresia of the esophagus in two successive male siblings. The first patient, born in September, 1946, was found at operation to have an atresia of the upper segment of the esophagus. The lower esophagus was observed to pursue a normal course through the diaphragm. The patient did not survive the attempt at surgical correction. The next infant, born to the same parents in November, 1947, had a congenital atresia of the esophagus, but gas was not observed in the stomach and intestines. A small amount of Lipiodol injected into the upper esophagus resulted in a bronchogram in the subsequent films. The patient died of peritonitis following the establishment of a gastrostomy. At autopsy, a fistula was found between the upper segment of the esophagus and the trachea at about the level of the tracheal bifurcation. The lower segment of the esophagus extended upward for about one inch and terminated in a fibrous cord. The mother gave birth to an apparently normal girl fourteen months later.

Pilcher[6] in a personal communication related two unreported cases of esophageal atresia. The first infant, a girl weighing 3 pounds, 12 ounces, was born on May 18, 1947, and was the first child of her 22-year-old mother. Labor had been induced at eight months because of a complicating hydramnios. The infant regurgitated all feedings and the diagnosis of an esophageal atresia was established when a catheter could not be passed into the stomach. The anus was more anterior than normal and a catheter could be introduced only 4 cm. into the rectum before meeting an obstruction. This finding, coupled with marked abdominal distention, made probable the additional presence of atresia of the colon. For these reasons it was decided not to undertake any surgical therapy. However, three days after birth, meconium was passed and plans were made to treat the esophageal atresia. Accordingly, a right transpleural thoracotomy was performed.

The proximal pouch of the esophagus lay in the thoracic inlet and the distal end of the esophagus reached the hilum of the lung. Because an end-to-end anastomosis of the esophagus could not be accomplished without excessive tension, the stomach was mobilized through the esophageal hiatus and an anastomosis of the stomach to the upper esophageal segment was made with a single layer of interrupted sutures of silk. Four ounces of clear, watery fluid escaped from the stomach when it was opened. The child did very poorly during the operation and several times was believed to have died. At the end of the operation her condition had improved slightly. Death occurred two hours later. An autopsy was not carried out. The large amount of clear fluid in the stomach, which did not contain bile, made probable an atresia of the upper portion of the gastrointestinal tract proximal to the bile duct.

Pilcher's second patient was born to the same mother on Sept. 22, 1948, there having been no intervening pregnancy. The patient was also a girl and weighed 7 pounds, 7 ounces. Normal delivery followed a full-term pregnancy.

A diagnosis of esophageal atresia with tracheoesophageal fistula was made thirty-six hours after delivery. Two days following birth, operation was performed through a right parascapular incision. The distal segment of the esophagus was well developed and entered the trachea above the carina. The tracheoesophageal fistula was divided and the fistula was closed with a single layer of interrupted silk sutures. The proximal segment of the esophagus overlapped the distal segment so that an anastomosis could be carried out without tension. The chest was closed without drainage. Feedings by mouth were started two days following operation. Ten days after operation the child was taking a full formula and breast feedings were begun on the following day. One month after operation, a barium swallow showed normal passage of the material through the esophagus. The child was discharged three days later.

Dorner[7] in a personal communication related two unreported cases of esophageal atresia in brothers. The first infant, who weighed 7 pounds and 4 ounces, was born on May 8, 1949. The mother had been treated for syphilis in December, 1947, but her serologic test for syphilis had become negative. The infant was admitted to the hospital three days following birth when he regurgitated feedings. A barium swallow showed esophageal atresia. An excessive amount of air was present in the stomach and intestines. The infant was deeply jaundiced and his temperature was 105.6° F. by rectum. In the four hours following admission, fluids were administered and the infant was given penicillin, dihydrostreptomycin, vitamins C and K, and a small transfusion of whole blood. Closure of the tracheoesophageal fistula and an end-to-end anastomosis of the esophagus were then carried out under local anesthesia. The infant did poorly during a part of the operation, but was resuscitated after an endotracheal tube was introduced and respirations were assisted. Although the condition of the infant was satisfactory upon completion of the operation, he suddenly became cyanotic ten hours later and could not be resuscitated. At autopsy the suture line was intact. There was an extensive and overwhelming bronchopneumonia.

The second child of the mother of Dorner's patient was a normal daughter. Her next child was a boy born on March 5, 1953. The infant regurgitated all feedings and was admitted to the hospital the day after birth. He weighed 7 pounds and was in good condition. Roentgenograms showed a blind upper esophageal pouch and air in the intestinal tract. On the morning following admission, when the infant was two days old, closure of the tracheoesophageal fistula and an end-to-end anastomosis of the esophagus were carried out under inhalation anesthesia. An extrapleural approach was used and, although a tear had been made in the pleura, the lung was expanded easily as the chest was closed. A No. 8 Fr. catheter was placed in the extrapleural space as a drain through a stab wound. The infant withstood the operation well. On the day following operation, however, he developed a right pneumothorax which was decompressed by means of an anterior intercostal tube. On the third day following operation, it was necessary to insert a posterior tube in order to evacuate fluid from the right chest. *Pseudomonas aeruginosa* was cultured from this fluid. A gastrostomy was done at this time for feeding purposes. The in-

fant developed a leak at the site of anastomosis and apparently the tracheal closure had also broken down. The infant died on the ninth day following operation. An autopsy was not permitted.

No other examples of esophageal atresia in siblings have been found in the literature, although Morse,[8] in 1920, reported the presence of esophageal stricture in brothers, and Ealing,[9] in 1940, mentioned the occurrence of esophageal atresia in cousins. In only one of the cousins, reported by Ealing, was the lesion confirmed by autopsy.

CASE REPORTS

CASE 1.—D. P., No. 665686, a 3-day-old white male infant, was admitted to the Pediatrics Service of the University Hospital on Nov. 18, 1949. His 24-year-old mother had had a normal pregnancy and delivery. The birth weight was 5 pounds, 14 ounces. The child regurgitated all feedings following delivery. A diagnosis of esophageal atresia with tracheoesophageal fistula was made by the referring physician when roentgenograms taken after an Iodochlorol swallow demonstrated esophageal obstruction at the level of the second thoracic vertebra and the presence of air in the intestines. The only other pregnancy of the mother, three years earlier, was complicated by toxemia and had resulted in a spontaneous abortion. The child's father, paternal grandfather, and paternal great-grandfather were said to have had congenital heart disease.

On examination the infant was a well-developed boy who was slightly dehydrated. His weight was 5 pounds, 7 ounces; temperature 100° F. by rectum. His color and cry were good. Respirations were quiet and dry, and the lungs were clear to percussion and on auscultation. The heart was normal. No other abnormalities were found. The laboratory findings were not remarkable.

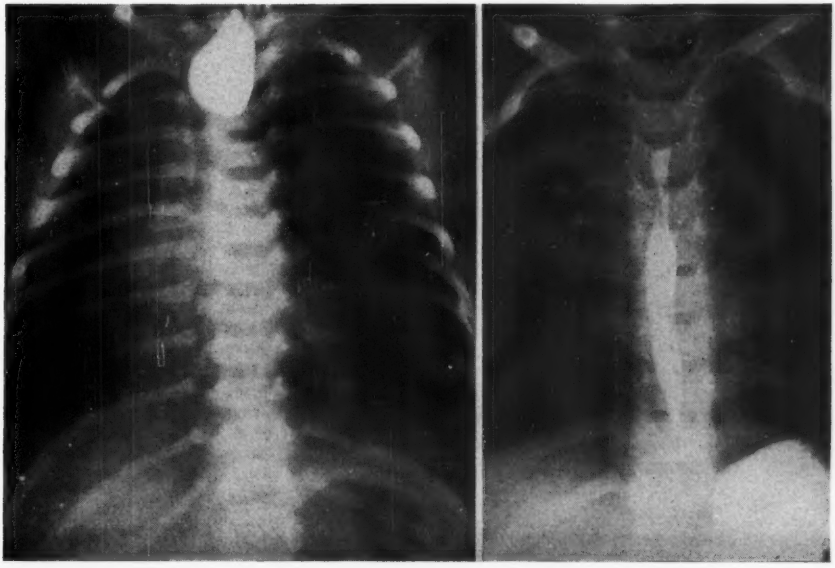
Roentgenograms: An Iodochlorol swallow performed before admission demonstrated esophageal atresia with a dilated proximal segment, the lower limit of which lay at the level of the second thoracic vertebra (Fig. 1, *A*). The lungs were clear. Air was present in the stomach and gastrointestinal tract.

Operation: On Nov. 19, 1949, four days following birth, after hydration had been accomplished, an infusion of blood was started in an ankle vein. A right parascapular incision was made and the posterior segments of the third, fourth, and fifth ribs were resected. The mediastinum was explored through an extrapleural approach. The proximal segment of the esophagus was found to bulge inferiorly to the level of the third rib posteriorly. The distal segment of the esophagus entered the trachea at its bifurcation. The distal segment measured 6 to 7 mm. in diameter and was larger than usual. The distance between the proximal and the distal segments measured 9 mm. The distal segment was divided 2 mm. from the trachea, and the opening in the trachea was closed in two layers with a continuous running suture of No. 6-0 silk on an Atraumatic needle. After the proximal segment had been mobilized, an incision 1 cm. in length was made in its tip. A two-layer telescopic anastomosis between the proximal and distal segments was carried out over a No. 8 Fr. catheter, using interrupted sutures of No. 6-0 silk. The proximal segment of the esophagus was tacked to the prevertebral fascia with a few interrupted sutures. The catheter was removed through the mouth. After irrigation of the extrapleural space and the instillation of a small amount of penicillin solution, a rubber wick was placed in the extrapleural space and brought out through the wound, and the extracostal muscles and subcutaneous tissues were closed in layers with interrupted sutures of No. 4-0 catgut. The skin was closed with No. 4-0 silk. The child withstood the procedure well.

Postoperative course: The child's condition remained good. On the second postoperative day, a gastrostomy was carried out for feeding. Fluid balance was maintained with intravenous infusions of 10 per cent glucose solution and subcutaneous infusions of 2.5 per cent glucose solution until full gastrostomy feedings were tolerated. The infant was given dihydrostreptomycin intramuscularly, 50 mg. three times each day, and penicillin intramuscularly, 200,000 units each day. One the fourth day following operation, the rubber

wick in the wound was completely removed after it had been shortened on preceding days. The wound healed well. Thirteen days following operation the child was allowed to swallow Iodochlorol. There was 50 per cent constriction of the esophagus at the site of the anastomosis, but no interference with the passage of the oil and no extravasation of the oil into the mediastinum. Seventeen days after operation, oral feedings were begun and the patient was able in six days to maintain his nutrition by oral feedings alone.

The infant was discharged Dec. 24, 1949, on a full diet by mouth. He weighed 6 pounds, 14 ounces. Following discharge he continued to gain steadily. The gastrostomy tube was removed elsewhere on June 7, 1950, and the gastrostomy closed spontaneously. The patient was readmitted on Sept. 28, 1951, with acute pharyngitis and tonsillitis. There had been some difficulty in swallowing during the attack. The child recovered and was discharged weighing 24½ pounds. A Rugar swallow at this time showed no evidence of narrowing of the esophagus (Fig. 1, *B*).



A. *B.*

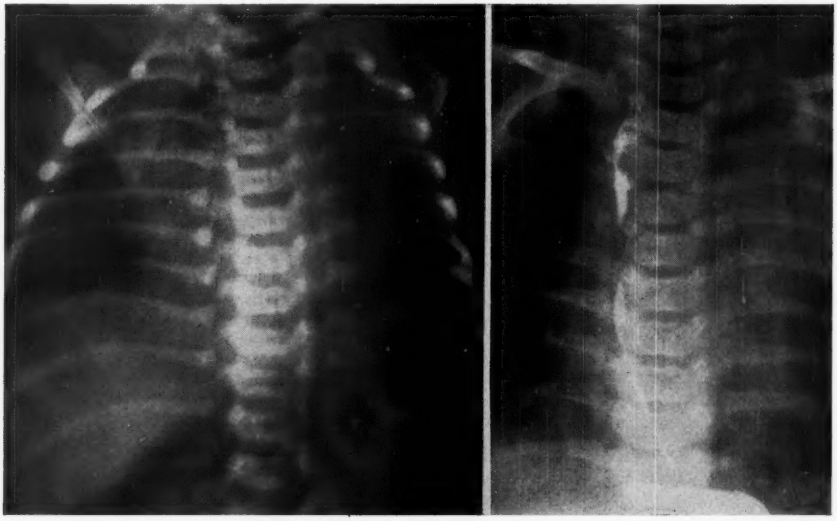
Fig. 1.—Case 1. D. P. *A*, An Iodochlorol swallow obtained Nov. 18, 1949, three days after birth, demonstrates a blind upper esophageal pouch. There is air in the stomach. *B*, A Rugar swallow obtained Oct 1, 1951. The esophagus is normal and there is no evidence of narrowing.

CASE 2.—T. P., No. 692857, the brother of the previous patient, was admitted to the Pediatrics Service of the University Hospital approximately five hours after birth on Nov. 1, 1950. The infant's physician had not been in attendance at the birth of the first patient, although he had been advised of the findings. The newborn infant was offered glucose solution which was regurgitated and the diagnosis was thereby suspected almost immediately after birth. The pregnancy had been normal and the delivery uncomplicated.

On examination, the infant appeared healthy and in no respiratory distress. His weight was 5 pounds, 11½ ounces; temperature, 97.8° F. by rectum; respirations 40; and pulse 128. Mucus drained from the mouth. The lung fields were dry and were clear to percussion and on auscultation. The heart was normal. The remainder of the physical examination was negative. The laboratory findings were not remarkable, although the hemoglobin was 20 Gm. and the red blood cells 5.4 million.

Roentgenograms: Fluoroscopy and spot films on admission, following the injection of Iodochlorol through a catheter, demonstrated atresia of the esophagus with dilatation of the upper segment, the lower limit of which was at the level of the third thoracic vertebra. A roentgenogram on the following day showed atelectasis of the right upper lobe. Air was present in the gastrointestinal tract (Fig. 2, *A*).

Operation: On Nov. 3, 1950, two days after birth, the mediastinum was explored through a right extrapleural approach following resection of posterior segments of the third, fourth, and fifth ribs. The distal segment of the esophagus entered the trachea just proximal to the carina. The proximal segment of the esophagus lay 1 cm. above the distal segment. The fistula was divided, leaving a 2 mm. cuff of esophageal tissue on the trachea.



A. *B.*

Fig. 2.—Case 2. T. P. *A*, Preoperative chest roentgenogram obtained Nov. 3, 1950. There is atelectasis of the right upper lobe. Air is present in the stomach.

B, An Iodochlorol swallow obtained April 2, 1951, demonstrates the esophagus lying to the right of the midline. There is slight narrowing of the esophagus at the level of the third thoracic vertebra. The Iodochlorol passes into the stomach without hesitation.

The fistula was then closed in two layers with a running suture of No. 6-0 silk on an Atraumatic needle. A tab of mediastinal tissue was tacked over this with a few interrupted sutures of No. 6-0 silk. The upper segment of the esophagus was freed and an incision 5 mm. in length was made in its tip. A No. 8 Fr. catheter was threaded through both proximal and distal segments and emerged through the mouth. An end-to-end anastomosis in two layers was carried out with interrupted sutures of No. 5-0 silk, the proximal segment being telescoped over the distal segment by the second layer. There was some difficulty in placing the posterior layers of the anastomosis and there was tension on the suture lines. The catheter was removed through the mouth.

The extrapleural space was irrigated with saline solution and a small amount of penicillin solution was placed in it. The inner end of a rubber wick was placed near the suture line and the wound was closed in layers around the drain with interrupted sutures of Nos. 4-0 and 5-0 silk. Prior to the closure of the wound, it was noticed that the atelectasis of the right upper lobe had cleared. The blood loss was calculated to have been 60 c.c. The infant received 85 c.c. of whole blood through an infusion in the saphenous vein. He withstood the operation well.

Postoperative course: In the immediate postoperative period the infant's condition continued to be good. He received intramuscularly 50 mg. of streptomycin four times each day, and 200,000 units of penicillin each day. Fluid balance was maintained with intravenous infusions of 10 per cent glucose solution and subcutaneous infusions of 5 per cent glucose solution. On the third day following operation the infant was allowed to swallow Iodochlorol. Roentgenograms showed the esophagus to be patent and there was no extravasation of the oil. Oral feedings were started on the following day. At this time removal of the rubber drainage wick was completed. On the ninth postoperative day, a small portion of the feedings was noted to have escaped through the posterior wound. Roentgenograms following an Iodochlorol swallow on the following day showed extravasation of the oil into the mediastinum. For this reason a gastrostomy was done for feeding. Drainage through the posterior wound gradually ceased and oral feedings were resumed on Nov. 27, 1950, after an Iodochlorol swallow showed a patent esophagus and no extravasation of the oil.

The infant was discharged on Dec. 6, 1950, weighing 6 pounds, 4¾ ounces. He continued to do well and his weight gain was steady. The gastrostomy tube was removed five months after operation. Examination of the esophagus at this time showed some narrowing but no delay in emptying of the esophagus (Fig. 2, *B*). The infant was last seen on June 4, 1951, when he weighed 15 pounds, 15 ounces, and was taking a normal diet. The parents have now moved to another state and re-examination has not been possible. A report, however, indicates that this patient and his brother are progressing well.

DISCUSSION

Esophageal atresia with or without tracheoesophageal fistula in children of the same parents has rarely been described. It had been felt that the possibility of this abnormality occurring more than once in siblings was almost nonexistent. The presence of esophageal atresia, however, has been confirmed in six pairs of siblings and suspected in two additional pairs. In the series of cases of atresia of the esophagus at the University of Michigan Hospital the anomaly has occurred in siblings only once in 182 families.

SUMMARY

1. Two brothers, born successively, were found to have esophageal atresia with tracheoesophageal fistula. Successful repair of the anomaly was carried out in both infants.

2. The known cases of verified or presumed esophageal atresia in siblings are reviewed. Since the presence of esophageal atresia in siblings has been verified only six times and suspected in two other instances, the probability of its occurrence more than once in a family seems remote.

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EARLY COMPLICATIONS FOLLOWING RESECTION FOR PULMONARY TUBERCULOSIS

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ACCUMULATED evidence shows that resection for pulmonary tuberculosis can be performed with a very low operative mortality.* However, the incidence of complications has not decreased to a corresponding extent. For this reason it seems important to review the more serious complications (Table I), which occurred following 355 consecutive pulmonary resections for tuberculosis performed at the Ray Brook State Tuberculosis Hospital between Jan. 1, 1950, and July 1, 1955, in the hope of discovering not only their causes, but also the most effective method of preventing and treating them. Residual air-containing pleural spaces, although no longer a serious problem, are also included in this study.

TABLE I

COMPLICATIONS		NUMBER
Operative spread of disease		3
Hemothorax		7
Atelectasis		1
Major wound sepsis		5
Bronchopleural fistula and empyema		20
a. with tuberculous empyema	7	
b. with probable tuberculous empyema	4	
c. with nontuberculous empyema	2	
d. without empyema	7	
Infected emphysematous bulla		1
Total		37

Three deaths due to pulmonary edema, cardiac arrest, and cause undetermined are not considered within the scope of the study.

Since some of the morbidity is due to tuberculous infection, it is of interest to note that 88 of 355 resections were performed upon patients with positive sputum by culture. Nine yielded organisms completely or partially resistant to three antituberculous drugs; 36, to two drugs; 17, to one drug; and 21, to none of the drugs tested. In 5 patients resistance studies were not available. Organisms were tested with 10 mcg. per ml. of streptomycin, 10 mcg. per ml. of para-aminosalicylic acid, and 5 mcg. per ml. of isoniazid. The patients received various regimens of these drugs at the time of surgery. Pyrazinamide and neomycin were also given to selected patients whose organisms were resistant to other drugs.

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*At Ray Brook there has been no operative mortality in the last 209 consecutive resections for pulmonary tuberculosis.

Operative Spread of Disease.—This complication, manifested by the appearance in the postoperative roentgenogram of parenchymal shadows which had not been observed preoperatively, occurred in three instances. Changes were transient in 2 patients, and cleared following repeated endotracheal aspiration and continued antituberculous drug therapy (Fig. 1). Two of the 3 patients had sputum positive for tubercle bacilli at the time of surgery. One patient with positive sputum, whose operation was performed early in this series, developed permanent pulmonary changes following the spread of disease. Drug therapy in this instance was not adequate according to present standards. It would appear, therefore, that operative spreads are to a great extent reversible, especially when the tracheobronchial tree is maintained relatively free of secretions and effective drug therapy is administered.

In this series, as well as one previously reported,[1] spread of disease did not occur in any instance in which the prone position was employed on the operating table.[2] The Carlens double-lumen catheter,[3] used in several instances, was apparently not as effective as the prone position as illustrated by the following case.

CASE REPORT

B. L., a 25-year-old housewife, underwent a resection of the apical and posterior segments of the right upper lobe for pulmonary tuberculosis on Nov. 1, 1954. Sputum at operation and the resected specimen were negative on culture for tubercle bacilli. Postoperatively the patient developed a hemothorax and evidence of a bronchopleural fistula. Sputum was blood-tinged and watery. Thoracentesis was unsuccessful because of the presence of clotted blood in the pleural cavity. On Nov. 8, 1954, the patient was taken to the operating room for a decortication and repair of the fistula. After endotracheal intubation the patient was turned from the supine to the left lateral decubitus position. Immediately, the tracheobronchial tree was flooded with pleural fluid. She was returned to the supine position, and the fluid was cleared from the respiratory passages. A Carlens catheter was passed; and the patient was again turned. Although the catheter appeared in proper position, with the balloons adequately inflated, fluid again poured into the dependent bronchi. The patient was quickly placed in the prone position with immediate improvement. The operation was then performed without further untoward incident.

Hemothorax.—Severe postoperative intrapleural bleeding occurred on seven occasions in this series. In five instances the patient was returned to the operating room and re-explored within a few hours of the original surgery. The blood clots were easily removed; and invariably the bleeders, when present, proved small and easily controllable. All of these patients did well. One patient was re-explored one week following resection (see Patient B. L.). In addition to the anesthesia difficulties, there was only fair postoperative re-expansion of the lung. One patient died without re-exploration. It is believed, in retrospect, that the fatal outcome might have been avoided had early re-exploration been performed. Because of experiences such as these, it is our policy to reoperate as soon as there is definite evidence of appreciable and continued bleeding. Use of the Bovie machine to coagulate chest wall bleeders during surgery has reduced the incidence of postoperative hemothorax.

Atelectasis.—More than transient atelectasis occurred in only 1 patient, who refused postoperative endotracheal aspiration. In all other instances, endotracheal aspiration was effective in preventing or alleviating atelectasis. It

A. *B.* *C.*

Fig. 1.—Operative spread of disease.
A, Preoperative roentgenogram.
B, Roentgenogram taken on the first postoperative day showing spread to left side.
C, Roentgenogram taken twelve days postoperatively showing complete clearing of the spread. This patient had negative sputum at the time of resection.

was necessary to perform tracheotomy on one occasion to facilitate frequent aspiration. Other aids in preventing the occurrence of atelectasis were preoperative control of secretions by postural drainage and antibiotics, careful aspiration of the bronchial tree during anesthesia, and administration of anesthesia in a manner which would permit early return of consciousness postoperatively.

Major Wound Sepsis.—This complication occurred in five instances. Three of these patients had culturable tubercle bacilli in the resected specimens, or sputum at the time of surgery. Staphylococci were cultured from four wounds. One wound yielded tubercle bacilli which were sensitive to the drugs administered. Three of the wounds were débrided and closed secondarily. Four wounds are now completely healed, and one is healed except for a small superficial portion.

Bronchopleural Fistula and/or Empyema.—Bronchopleural fistula, defined as a more than transient communication between the bronchial tree and the pleural cavity, occurred on twenty occasions. Undoubtedly, unidentified fistulas occurred in the group of cases classified as residual air-containing pleural spaces. However, only proved cases of fistula are included in this analysis.

The complications of bronchopleural fistula are summarized in Table II. Tuberculous empyema occurred only in patients from whose sputum at the time of resection, or resected specimens, tubercle bacilli could be cultured. Four of these patients still have "active"* disease. In 3 patients the empyemas are small and improving. One patient has had a recent additional resection and is now doing well.† The only death occurred in a patient who refused treatment.

Table III lists the therapy for bronchopleural fistulas and empyemas. Although many surgical procedures are listed, all are designed to obliterate dead space, a fundamental principle in the treatment of empyemas.

Residual Air-Containing Pleural Space.—Prior to the adoption of the routines to be discussed, residual air-containing pleural spaces occurred quite frequently following resection. It was formerly my practice to obliterate these spaces by thoracoplasty within a few weeks after resection, at which time the pleural cavity was often explored. Not uncommonly, small air leaks could be demonstrated from the lung surface, even in cases where fistulas had been unsuspected clinically. Thoracoplasty, with or without suture of the fistulas, was with few exceptions successful in obliterating the air spaces. With the lapse of time it became obvious that in patients from whose sputum, or resected specimens, tubercle bacilli could not be cultured, tuberculous infection did not seem to occur. Indeed, nontuberculous empyema rarely occurred; and such pleural air spaces have been observed for many months without complications. The presence of a bronchial communication rarely altered the situation (Fig. 2). On the other hand, when tubercle bacilli could be cultured from the sputum, or resected specimen, tuberculous empyema often occurred if the dead space was not quickly eliminated.

*National Tuberculosis Association (1950) Classification.

†This operation is not listed in Table III, since it has been performed too recently to evaluate results.

TABLE II. BRONCHOPLEURAL FISTULA

	PATIENTS	WITH NEGATIVE* CULTURES	WITH POSITIVE* CULTURES	WITH ORGANISMS* RESISTANT TO			WITH ORGANISMS* RESISTANT TO ALL AVAILABLE DRUGS AT RESECTION	RESULTS N.T.A. CLASSIFICATION (1950) OF PATIENTS AT LAST FOLLOW-UP			
				ONE DRUG	TWO DRUGS	THREE DRUGS		ACTIVE	ARRESTED	INACTIVE	DEAD
TOTAL	20	7	13	2	2	5	1	4	1	14	1§
A. With tuberculous empyema	7	0	7	2	1	1	0	1	0	5	1§
B. With probable tuberculous empyema†	4	0	4	0	1	3	1	3	0	1	0
C. With nontuberculous empyema‡	2	2	0	0	0	0	0	0	0	2	0
D. Without evidence of empyema	7	5	2	0	0	1	0	0	1	6	0

*Cultures for tubercle bacilli from resected lung or sputum at the time of resection.
†Although cultures of pleural space are not available, clinical evidence supports a diagnosis of tuberculous empyema.
‡Both of these were staphylococcal infections.
§This patient left the hospital about two weeks postoperatively.

TABLE III. THE TREATMENT OF TWENTY PATIENTS WITH BRONCHOPLEURAL FISTULA

TREATMENT	WITHOUT EVIDENCE OF EMPYEMA	NONTUBERCULOUS EMPYEMA (STAPHYLOCOCCUS)	PROBABLE OR PROVED TUBERCULOUS EMPYEMA		RESULTS N.T.A. CLASSIFICATION (1950) OF PATIENTS AT LAST AVAILABLE FOLLOW-UP			
			RESISTANT* TO ALL DRUGS	SENSITIVE*† TO AT LEAST ONE DRUG	ACTIVE	ARRESTED	INACTIVE	DEAD
No surgical treatment	2			2	1	1	1	1§
Decortication	1	1					1	
Decortication and suture of fistula	3		1	2	1‡		6	
Decortication, suture of fistula and resection of lung				2	1‡		1	
Thoracoplasty	1			3	2		2	
Thoracoplasty and drainage of empyema			1		1			
Thoracoplasty, decortication and repair of fistula				1			1	
Thoracoplasty and decortication		1					1	
Thoracoplasty, additional resection and repair of fistula				1			1	

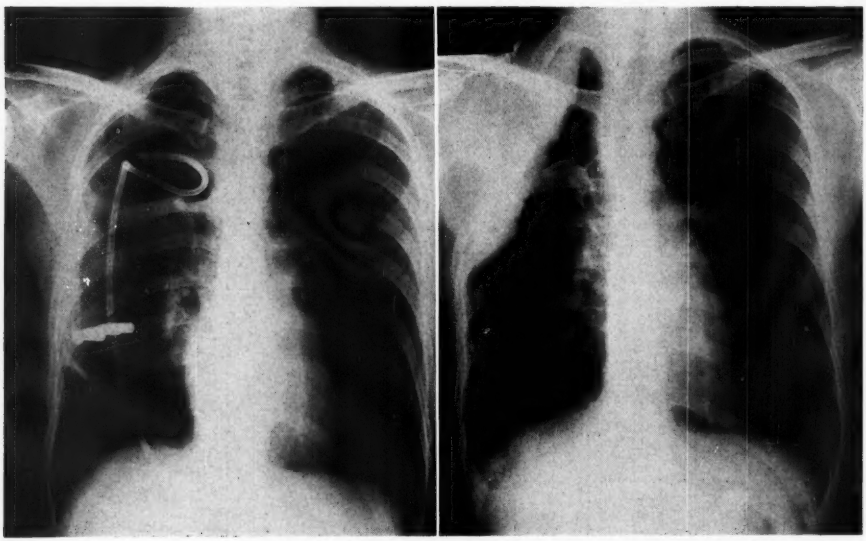
*Sensitivity of tubercle bacilli from sputum or pleural space to drugs available for treatment of fistula.

†Organisms are considered sensitive to available drug not previously employed, when resistant studies are not available.

‡These two "actives" represent failure of the procedure to cure the patient. Both patients later became "inactive" following other procedures.

§This patient left the hospital about two weeks postoperatively.

Since the adoption of the following practices several years ago, persistent pleural air pockets have occurred infrequently. Space-filling thoracoplasty has been rarely necessary, except after pneumonectomy. The theoretically deleterious effects of overdistention on the course of tuberculosis in the remaining lung tissue have not been evident, in my experience or that of others.[4] At resection, the lung is freed sufficiently of adhesions to allow it to reaccommodate the pleural cavity. Chest wall bleeders are carefully coagulated with the Bovie machine. Following resection, air leaks are carefully controlled. Except following wedge resections, and in rare instances of advanced pulmonary emphysema, when air leaks are difficult to control, the raw surfaces of the lung are not approximated by suture. Two catheters



A *B*

Fig. 2.—Bronchopleural fistula without empyema following resection of apical and posterior segments of right upper lobe. Intercostal catheter suction (*A*) and thoracoplasty (*B*) were unsuccessful in obliterating the postoperative pleural air space.

are employed for drainage; the tip of one is sutured to the apical pleura, and the tip of the other is led to the base posteriorly. I early abandoned underwater-seal drainage, as it depends for effectiveness on the ability of the patient to cough, which is often erratic in the early postoperative period when effective drainage is needed most. Moreover, with gradual pulmonary expansion, which often occurs when this type of apparatus is used, the base of the lung may become adherent in a position too far caudad to allow the pulmonary apex to reach the dome of the pleural cavity. Low negative pressures of −10 to −15 cm. of water have many of the same disadvantages, since the lung may not be held firmly in contact with the parietal pleura, a condition which promotes early agglutination of the pleural surfaces. Negative pressures of

C. *D.* *E.*

Fig. 2.—Cont'd. (*C* and *D*) Fistula demonstrated by bronchogram. If fistula had not been demonstrated this might have been classified as a residual air-containing space. (*E*) Eighteen months following thoracoplasty the pleural space has disappeared spontaneously.

–25 to –40 cm. of water are often necessary. However, the degree of negative pressure required may be reduced by maintaining the patient in a reclining position until air leakage and fluctuation of fluid in the drainage tubes have ceased.

As in complicated bronchopleural fistula, the most effective surgical procedures in the treatment of residual air spaces are thoracoplasty or pulmonary decortication with or without suture of fistulas, if present. Many spaces will disappear spontaneously (Fig. 2). Occasionally, before firm pleural symphysis has occurred, intercostal catheter drainage may be effective. However, prolonged intercostal drainage should be avoided as secondary infection may supervene.

Infected Emphysematous Bulla.—This complication occurred in 1 patient who had pulmonary emphysema. Tubercle bacilli were cultured from the resected specimen and from the bulla. The infection cleared after Monaldi drainage and further therapy with drugs to which the organisms were sensitive.

DISCUSSION

Complications following resection for pulmonary tuberculosis may be due to a number of factors. Surgical technique, choice of operation, diligence of pre- and postoperative care, and patient cooperation are some of the important ones which are difficult to measure. Complicating diseases often influence the outcome of a procedure. However, except perhaps for bacteriology, extent of disease is most important. Although it has been possible in this series, and in one previously reported,[1] to remove with good results cavitary disease, leaving behind appreciable residual nodular disease, it is to be expected that in these cases the incidence of complications will be higher than in those from which all palpable disease can be removed.

That bacteriology is an important consideration is indicated by the fact that tuberculous complications did not occur in this series in any patient from whose sputum at the time of surgery, or resected specimen, tubercle bacilli could not be cultured. Shefrin,[5] reviewing our surgical material, has found that tubercle bacilli can be cultured from 10 per cent of the resected specimens from patients whose sputum has been negative on culture for four months or longer prior to resection. It appears, therefore, that by proper selection of cases one can almost eliminate tuberculous complications.

Because of these considerations one should question the advisability of performing resection, in the absence of other compelling factors, upon patients with positive sputum who have received only one or two weeks of antituberculous drug therapy. The advocates of such early surgery have claimed that complications are fewer than if surgery were delayed until later, when patients may have drug-resistant organisms. There are several defects in such reasoning. First, after several months of continuous combined drug therapy the great majority of patients will have negative sputum. Some will have improved sufficiently to require surgery no longer. Those who do come to resection with negative sputum will be subjected to minimal risk of tuber-

culous complications. Moreover, even if drug-resistant organisms appear in appreciable numbers, it is rare that they are at once resistant to all available potent antituberculous drugs.

SUMMARY

Early complications following resection for pulmonary tuberculosis occurring over a period of five and one-half years are reviewed. Prophylaxis and treatment are discussed.

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RESTORATION AND RECONSTRUCTION OF THE TRACHEA AND MAIN BRONCHI

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ORGANIC obstruction of the trachea and of the main bronchi, requiring reparative surgical treatment is rare, and the experience in this field of any surgeon, in the less densely populated areas, must be limited. The local lesion is usually a sequela to accidental trauma, tuberculosis, or benign tumor. Local resection of a malignant tumor of the main bronchus is occasionally warranted in cases in which it is of paramount importance to conserve respiratory tissue and, at the same time, to give the patient a chance of surgical cure. In such rare contingencies, total ablation of the tumor with the involved lobe has been planned and reanastomosis of the upper or lower lobe bronchus, respectively, to the trachea performed.

These surgical developments have been the direct outcome of experimental work and clinical applications foreseen and practiced by Kirschner (1909), Hohmeier (1911), Neuhof (1917), Taffel (1940), and Daniel (1948). It was shown by Belsey (1946), in a report of the first extensive reconstruction of the human trachea, that immediate continuity could be restored by means of an airtight membrane (fascia lata) supported on a skeleton of wire along which normal mucosal continuity was effected by regeneration. Following further development of this concept by Rob and Bateman (1949) and by Gebauer (1950), authority has been given for the rapid clinical development of tracheobronchial resection and repair by suture and graft.

The successful development of homologous arterial grafts, preserved by tissue culture methods and by lyophilization, has not been reduplicated with bronchial tissue. Experimental grafting of autogenous and homologous tracheal segments has been unsuccessful in the main, the graft being replaced by granulation tissue without cartilaginous support, subsequently giving rise to respiratory obstruction.

In recent years, the clinical trial of tracheobronchial resection with resuture or graft, has been illuminated by the outstanding work of Gebauer (1950, 1953).

The scope of this paper is to discuss our limited experience in treating obstructive lesions of the trachea and main bronchi.

CERVICAL TRACHEA

Our clinical experience is only partly relevant to this paper. It is confined to the symptomatic treatment of asphyxia from compression, to the per-

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manent restoration and support of the tracheal lumen, and to the consideration of reconstruction in a case of carcinoma. This is briefly summarized and reference is made to specific cases.

Clinical material has been limited to 10 patients with constriction from thyroid adenomata, all of whom have been relieved, and the trachea restored by removal of the tumor via a collar incision in the neck, usually without recourse to splitting the sternum; to 1 patient with Hodgkin's disease of the thyroid gland; and to 1 patient with advanced carcinoma of the trachea. There have been no cases of benign tumor (cylindroma) or of injury. No local reconstruction has been performed.

In the patient with recurrent thyroid carcinoma, involving the upper five rings of the anterior and lateral walls of the trachea (Case 1), resection and reconstruction was abandoned in favor of excision of the larynx and upper trachea, as the growing edge of the tumor could not be delineated.

In the patient with Hodgkin's disease, the cervicothoracic trachea was compressed to an anteroposterior slit by a scirrhous tumor enveloping the visceral structures of the neck. It was possible to free the trachea, the esophagus, and great vessels completely on their anterior and lateral aspects, and to anchor the thinned and collapsed cartilages by laterally placed sutures extending to the cervical tissues and close the wound without tracheotomy. Convalescence was uneventful.

In the other patient with advanced carcinoma of the trachea, a woman, 84 years of age, in whom there was a compression of the tracheal lumen to an anteroposterior slit by a large growth extending behind the esophagus, it was possible to relieve the obstruction by local removal of the growth from the neck using the usual incision combined with splitting of the manubrium sterni. A tracheotomy tube was inserted on completion to allow time for healing. There was considerable relief but there was rapid progression of the disease and an early death from tracheoesophageal fistula.

Recurrent Carcinoma of the Thyroid.—

CASE 1.—G. S., farmer, aged 64. The patient, referred by Mr. P. Eisdell Moore, was admitted to the hospital complaining of severe hemoptysis and hoarseness of the voice. Thyroidectomy had been performed two years previously for carcinoma, and although he had been well for the following year, he was troubled by an occasional cough, huskiness of the voice, and an increasing swelling under the thyroid scar.

On physical examination, there was a densely hard growth in the midline of the neck, fixed to the trachea and extending up to the thyroid cartilage and downward on the trachea. The lower extremity reached to within 1½ inches of the sternal notch. At bronchoscopy (a bloody affair), there was little movement of the vocal cords and just below them a friable, ulcerating hemorrhagic tumor was seen to occupy the anterior and lateral walls of the trachea for 1 inch.

A full course of deep x-ray therapy was given after which the growth was re-assessed by bronchoscopy. The vocal cords, although less mobile than normal, were considered to show improvement from the previous examination and the growth was thought to have become less extensive, less vascular, and more amenable to examination. The tumor was seen to extend as a sessile, red, ulcerating mass to within 1½ inches of the glottis and to occupy the anterior and lateral aspects of the trachea for 1½ inches. The criteria for

resection were fulfilled as the tumor appeared to be localized, anteriorly placed, did not involve the recurrent laryngeal nerves, and was so situated as to allow room for the insertion of an inlay below the cords.

Laryngectomy and excision of the proximal 2 inches of the trachea was performed after thoroughly exploring the possibility of local excision of the tumor and reconstruction of the trachea. A horseshoe incision with the two feet extending upward to the thyroid cartilage was made through densely fibrotic tissue to expose the operation site. Tumor or fibrous tissue was found to extend upward and to involve the upper five rings of the trachea, and the cricoid and thyroid cartilages on their anterior and lateral aspects, and there was an encapsulated and glandular mass above which there was considered to be carcinoma.

It was not possible to isolate the recurrent laryngeal nerves from this tissue during excision of the tumor mass from the anterior and lateral aspects of the trachea, cricoid and thyroid cartilages, at which sites there was no proper demarcation. The consensus of observers was that conservative operation would have been inadequate for carcinoma considering the risk of recurrence. Despite preparations for reconstruction by a dermis graft attached to tantalum mesh, the operation was abandoned in favor of laryngectomy with excision of the upper trachea, cricoid and thyroid cartilages, together with a block dissection of the upper deep cervical glands. The stump of the trachea was sutured to the skin after deepening the sternal notch. The pharynx was reconstituted and a Ryle's tube passed into the stomach for feeding purposes.

Comment: The convalescence of the patient was uneventful and speech became possible with an esophageal voice. There has been no recurrence (18 months). Under the circumstances, local resection would have been deplorable and contrary to the principles of cancer surgery which require a block removal of involved tumor together with the draining lymphatic glands. There would be few and very infrequent exceptions to this rule.

Tracheal reconstruction by a cylindrical dermis graft on tantalum mesh, as carried out in the cadaver and the pig (see Fig. 3), would have been suitable for a localized tumor of low grade malignancy, such as cylindroma or adenoma of the trachea. In such a case, difficulty would not be anticipated in displaying the recurrent laryngeal nerves. In the presence of malignant infiltration and fibrosis, this dissection is hopeless.

Hodgkin's Disease of the Thyroid Gland.—

CASE 2.—Mrs. F. S., aged 26. This patient was admitted in poor condition from the Cook Hospital (Dr. R. Hall) in considerable distress, suffering from respiratory obstruction with cyanosis, stertorous breathing, and a pulse of 120.

An attempt at thyroidectomy had been made a year previously. At this operation such insuperable difficulties were encountered owing to the hard, fibrous, infiltrating nature of the growth, that the operation was abandoned after ligature of the left internal jugular vein and injury to the left recurrent laryngeal nerve. A diagnosis of Riedel's struma and Hodgkin's disease, respectively, was made by two independent pathologists.

A wheeze, which was noticed six months prior to admission, had become increasingly severe over the past few months following an acute respiratory infection.

On examination, she was distressed and cyanosed with stertorous breathing, a rapid thready pulse, and distended neck veins. There was a firm, densely hard, irregular mass occupying the distribution of the greatly enlarged thyroid gland and extending down into the chest and compressing the tracheal wall to a slit opposite the bodies of the first, second, and third dorsal vertebrae. There was no improvement in an oxygen tent and urgent operation was undertaken.

The compression was noticed to be mainly, but not entirely, from the left side. In the course of bronchoscopic examination, on the operating table under local anesthesia, performed in the sitting position owing to the patient's imminent danger of asphyxia, the tracheal lumen was visualized as a slit just beyond the glottis, the mucosa apparently not being involved.

A cuffed intratracheal tube was passed beyond the tumor and general anesthesia (Pentothal and curare) induced (Dr. Anson). The neck veins were greatly distended and bled freely although oxygenation was satisfactory.

With the patient in the semirecumbent position, the tumor was exposed by a collar incision with a T-shaped extension downward, dividing the sternum through to the third interspace and retracting the margins widely.

A massive, irregular, hard growth extending upward to the thyroid cartilage and downward to the tracheal bifurcation, especially on the left side where it had been demonstrated by x-ray, was found to encircle the trachea and the esophagus as well as the carotid sheath on either side, as a scirrhous collar, and to compress the great veins and aortic arch and its branches until the trachea was identified. It was possible to extricate the carotid sheath on either side from the encircling tumor. At this stage, the left jugular vein was noted to be a fibrous cord, a sequela of the previous operation. The tumor was

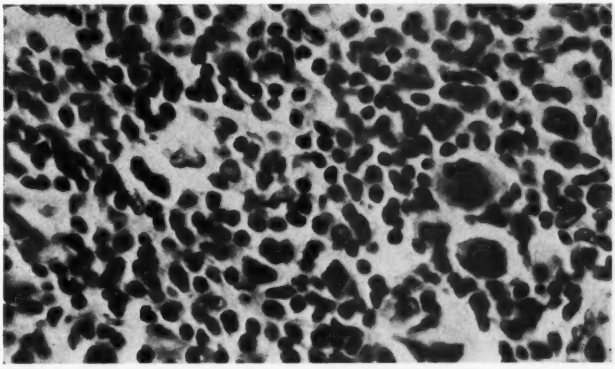

Fig. 1.—Case 2 (F. S.). Histologic section confirming the diagnosis of Hodgkin's disease.

densely adherent to, but not infiltrating, the trachea which was compressed so as to resemble a scabbard. It was freed in front and laterally, the tumor being divided at the posterolateral quadrants to avoid damaging the recurrent laryngeal nerves. The dissection was carried upward on either side removing the upper poles of the thyroid gland together with a few fleshy lymphatic glands in this region. Some apparently normal thyroid tissue was left at the upper pole on the left side.

By means of several sutures placed between the lateral walls of the softened trachea and the adjacent fibrous tissue, the walls were fixed apart to establish a lumen. The sternum was approximated with wire sutures and the skin closed, leaving two small open drains into the anterior mediastinum. After removal of the intratracheal tube, there was a normal air passage and the patient was returned to the ward and placed in an oxygen tent.

A course of deep x-ray therapy to the neck was given for Hodgkin's disease and her immediate recovery was uneventful. Cellular elements, typical of Hodgkin's disease, infiltrating and largely replacing the thyroid gland (Fig. 1), were confirmed by Dr. S. Williams after histologic examination of the specimen. She remains well.

Comment: 1. The trachea was compressed by the tumor (as distinct from infiltration by carcinoma) and the obstruction was relieved by removal of the

tumor. 2. Tracheotomy was not possible and indeed undesirable, either before or after the operation. 3. Anesthesia was made possible by the insertion of a McGill tube under local anesthesia with the patient in the sitting position. 4. After operation, it was found possible to support the flaccid trachea by laterally placed sutures. If these had not been satisfactory, it was planned to splint the tracheal walls with steel mesh.

Discussion.—Local excision and reconstruction is reserved for patients with low-grade local malignancy, which as a group, do not respond favorably to deep x-ray therapy. The local extensibility of the trachea makes it possible to excise 1 inch or more of trachea and to reanastomose the ends (Fig. 2). This is facilitated if the posterior wall is able to be preserved.

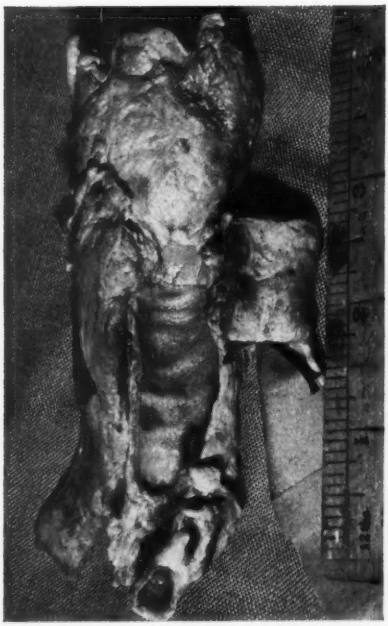

Fig. 2.

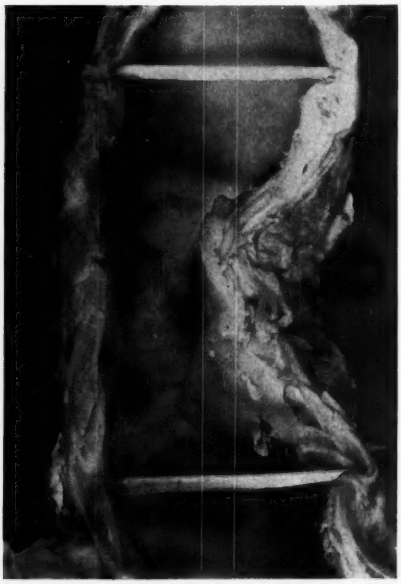

Fig. 3.

Fig. 2.—Human trachea after excision and reanastomosis of the ends. Post-mortem specimen.

Fig. 3.—Cervical trachea of a pig opened from behind. Sacrificed six weeks after excision of the anterior and lateral walls and restoration by a tantalum supported dermis graft. The mucosa has almost regenerated over the tantalum mesh.

In other cases, defects, which have been left after excising the tumor, can be satisfactorily sealed by using an airtight patch of dermis supported on the inner aspect with tantalum mesh (Fig. 3).

In the presence of inoperable malignant disease, tracheotomy is to be avoided if possible as the tube interferes with radiation of tumors, which are usually resistant anyhow, and malignant cells are likely to grow along the sinus.

Local measures may be necessary to support a flaccid trachea after removal of a tumor compressing it.

THORACIC TRACHEA

Experience in reconstituting the thoracic trachea has been limited to three cases, each of which presented a different problem: (1) Local excision of a tracheal carcinoma and repair using a free graft (Case 3). (2) Local plastic reconstruction by a longitudinal incision and transverse suture (Case 4). (3) Tracheal replacement by insertion of a viable bronchotracheal graft to replace tissue lost by stricture (Case 5).

Fig. 4*A*.—Case 3 (I. B.). Primary carcinoma of the trachea. Lateral chest x-ray showing the position of the tumor.

CASE 3.—I. B., aged 58, medical practitioner. The patient was a heavy smoker. There was a history of cough becoming increasingly severe over the past few months, loss of appetite, and loss of weight and stridor.

Physical examination: There was little of note apart from a hard gland in the supraclavicular region which was reported as showing chronic granulomatous changes. A circumscribed mass was demonstrated radiologically in the superior mediastinum between the esophagus and the trachea and just above the aorta (Fig. 4*A*). The Wassermann reaction was negative. At bronchoscopy (Dr. McDowell), a rounded, firm, nodular tumor, about 2 inches in diameter, was seen protruding through the right posterolateral wall of the thoracic trachea and extending downward to just above the carina. At thoracotomy (Oct. 25, 1950—Mr. D. Robb and R. N.), a hard, irregular, rounded tumor was felt arising as an oval projection 2½ inches in length from the right side of the trachea and extending upward from just above the curve of the azygos vein. The overlying lung, adherent but not infiltrated, was excised and examined. An intratracheal tube was able to be manipu-

lated so that the tip passed beyond the proposed excision of the trachea leaving the balloon adjacent to the deficiency. An oval window of trachea containing the tumor, together with a piece of esophagus, was excised. The defect in the trachea was closed at either end by direct suture and the central deficiency filled by a firm patch of atelectatic middle lobe of the lung covered by pleura on both sides. The esophageal wall was reconstituted by suture.

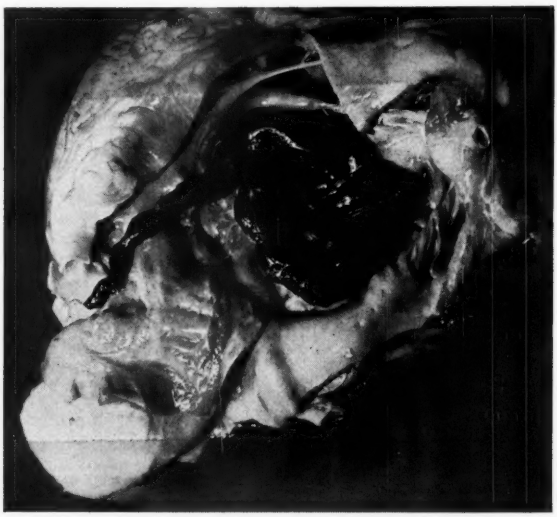

Fig. 4*B*.—Cardiac embolus which caused sudden death.

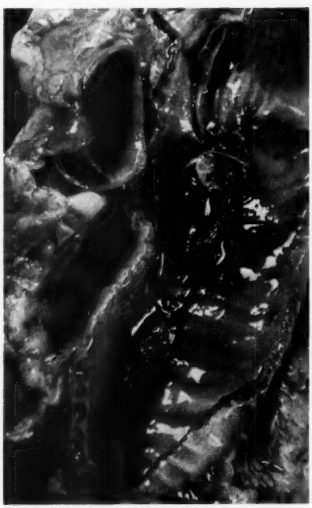

Fig. 4*C*.—Post-mortem specimen of the trachea showing the position from which the tumor was excised and the well-sealed tracheal deficiency.

The specimen was reported as being an anaplastic carcinoma of the trachea apparently of basal-cell type with malignant infiltration of the esophagus.

Apart from tachycardia and a temperature rising to 100° F, the postoperative recovery was uneventful until the eighth day when sudden death occurred.

At post-mortem, there was an acute obstruction of the heart by a cardiac embolus 14 inches in length arising from the inferior vena cava (Fig. 4*B*). The tracheal lumen, slightly narrowed above and below by sutures, showed an oval window 1½ inches in length by ¾ of an inch in width, repaired by a patch of lung covered on the pleural surface by a smooth layer of fibrin (Fig. 4*C*). There were residual malignant glands all along the trachea. By histologic examination, there was shown to be a tissue reaction of the perichondrial supporting tissues of the trachea infiltrating into the necrotic patch and characteristic of the early stages of repair.

Comment: A patch of firm lung tissue was found to seal the tracheal defect, pending natural repair. This technique originally used for reinforcing the raw bronchial stump (Churchill, 1939), has been superseded by methods in which the tracheal lumen can be reconstituted and maintained regardless of the amount of tissue excised.

Fig. 5*A*.—Case 4 (B. L.). Tracheogram showing tracheal stenosis opposite the inner end of the clavicles.

CASE 4.—B. L., aged 24, occupational therapist. This patient had pulmonary tuberculosis, first recognized in 1947 at which time an x-ray of the chest showed minimal infiltration and sputum tests were positive. Symptoms of persistent cough and inspiratory stridor together with a wheeze and dyspnea were first complained of in October, 1953, and despite ten weeks' treatment with streptomycin 1 Gm. three times weekly, and para-aminosalicylic acid, there was no improvement. At bronchoscopy (Dr. C. McDowell), 2½ inches from the vocal cords, the tracheal lumen was seen to be reduced to about 5 mm. in diameter by tuberculous granulation tissue reminiscent of polyps. This was treated locally by painting with 30 per cent silver nitrate, and systemically by antituberculous drugs. After one month of treatment, there was still a severe stridor, and at bronchoscopy, the presence of

a fibromembranous stenosis was seen, 1½ cm. above the carina. After negotiation of the stricture by the bronchoscope, the right stem bronchus was shown to be narrowed at its entrance, but covered by healthy mucous membrane.

There was progressive increase in stridor and respiratory distress over the next two months, and at a later bronchoscopy, the membranous tracheal stenosis was shown to be almost complete. The stricture was graphically visualized by tomography and by a tracheogram (Fig. 5*A*). Operation was undertaken on Dec. 21, 1953.

The chest was opened through the sixth intercostal space removing segments of the second to sixth ribs, posteriorly. The lung, reasonably healthy in apearance, was freed in the extrapleural plane and the azygos vein divided between ligatures. The thick vascular pleura over the trachea was incised to the thoracic inlet to give better exposure. After incision and dissection of the peritracheal fascial envelope, the fibrous stenosis was found (Fig. 5*B*). It was without supporting cartilaginous rings and about ¾ of an inch in

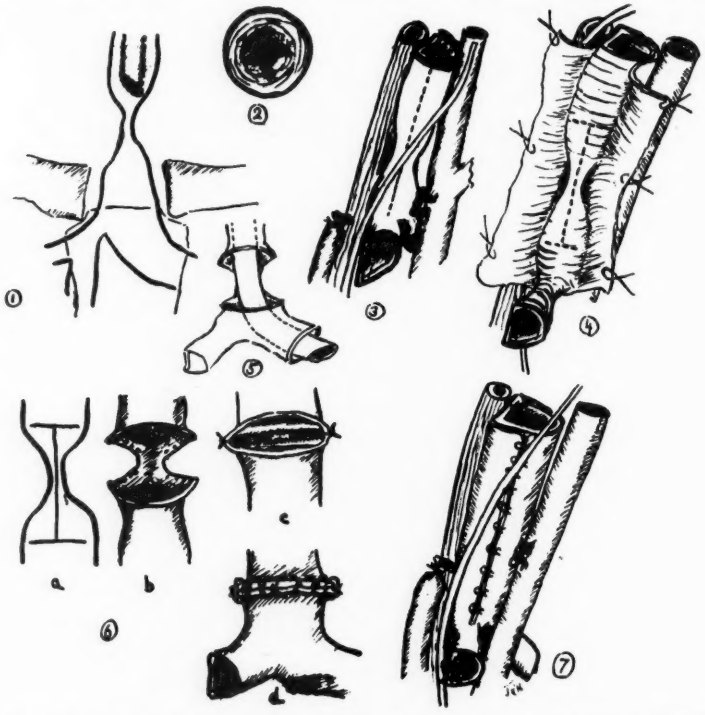

Fig. 5*B*.—Case 4 (B. L.). Diagrammatic outline of the steps in the reconstruction. The intratracheal tube is in position, *1;* above the stricture, *2*. The appearances at thoracotomy after ligation of the saphenous vein are shown in *3*, and after reflection of peritracheal fascia in *4*. The stages in the tracheoplasty are shown in *6 a,b,c,d*. The final appearances are shown in *7*.

length. After insertion of traction sutures into the adventitia and palpation of the upper end of the stricture, a transverse incision was made into the trachea immediately above this and a vertical extension made downward for 1 inch, dividing the stricture visible as a fibrous ring 3 mm. in diameter. The intratracheal tube was advanced down the left bronchus and respiration resumed without any air leak despite the lack of cuff. A gap in the trachea, 1½ inches long but with the posterior wall intact, was now present but sealed with the intratracheal tube. The trachea having been mobilized up to the neck earlier in the operation, and a rubber loop having been placed for traction, it was found possible to

draw the upper and lower edges of the tracheal incision together by everting mattress sutures, thus completely relieving the stricture. On completion, the intratracheal tube was pulled up and the anastomosis tested. After suture of the peritracheal fascia, the pleura was reconstituted. The upper lobe bronchus was healthy but narrow.

The postoperative course was uneventful and the symptoms were completely relieved.

The patient was readmitted urgently on March 11, 1954, with asphyxial symptoms and at bronchoscopy the operation site was obliterated by large edematous polypoid granulations over the black silk sutures protruding into the trachea. After removal of these

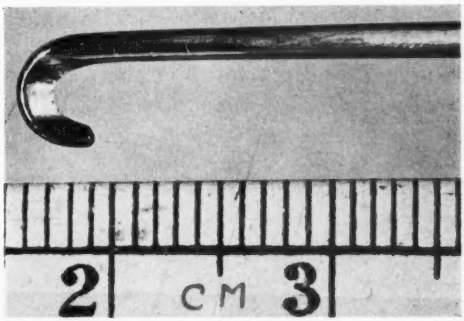

Fig. 5*C*.—Photograph of stitch-cutter described in the text.

Fig. 5*D*.—Postoperative tracheogram a year later showing restoration of the normal lumen.

watery polyps, the tracheal lumen was shown to be entirely satisfactory. There have been further bronchoscopic examinations from time to time with removal of granulations and of stitches divided by a special stitch-cutter (Fig. 5*C*), and cauterization with 30 per cent silver nitrate. The condition has healed and has required no further treatment over the past seven months (Fig. 5*D*).

Comment: (1) The local endobronchial disease occurred without serious general disease possibly from the submucosal spread from the lymphatics of the upper lobe of the lung. There was local clearing of the disease following applications of silver nitrate and the giving of antituberculous drugs, but the stricture formation was progressive with healing. (2) The extensibility of the trachea was quite remarkable. This fact was made use of in the repair which at first sight seemed impossible. The plastic operation was found to be easier than complete division. (3) There was considerable polypoid reaction about the stitches. Obstruction was caused and asphyxia only averted by urgent bronchoscopic removal. There was difficulty in removing the stitches in the initial stages but this problem was solved by the use of the special stitch-cutter.

Fig. 6A.—Case 5. Tuberculous stenosis of trachea and left stem bronchus. Before operation.

CASE 5.—M. R., a 22-year-old woman,* gave a history of tuberculosis, complicated by asthma since 1944 at which time a right artificial pneumothorax was induced for infiltration of the upper and middle lobes of the lung. There was deterioration in 1948, at which time there was shown to be a cavity in the left upper lobe, 2 inches in diameter, for which a seven-rib thoracoplasty was performed with subsequent conversion of the sputum. The right artificial pneumothorax was discontinued in 1950, the patient remained well until 1952 when severe asthma and a wheeze was noticed. At this time, the trachea was seen, at bronchoscopy, to be narrowed to the diameter of a lead pencil by scarring

*Case history published in the Brit. J. Surg. 42: 174, 1955.

and active tuberculous granulations which extended upward from the carina for 2 inches. Treatment with streptomycin and isoniazide was continued for six weeks, at the end of which time, although the sputum was negative, there was considerable stridor.

The patient was admitted urgently in May, 1953, suffering from asphyxia which was relieved by sedation and oxygen. The tracheal lumen was seen, at bronchoscopy, to have undergone progressive narrowing without ulceration to the size of a goose quill, at the site previously mentioned. A visual record of the lesion was obtained by a bronchogram. Tracheal stenosis, 2 inches in length, was demonstrated extending upward from the carina (Fig. 6*A*). There was an apparently normal segment of the left stem bronchus below this and proximal to a second stenosis at about the origin of the left upper lobe bronchus. There was some distention to the right bronchial tree.

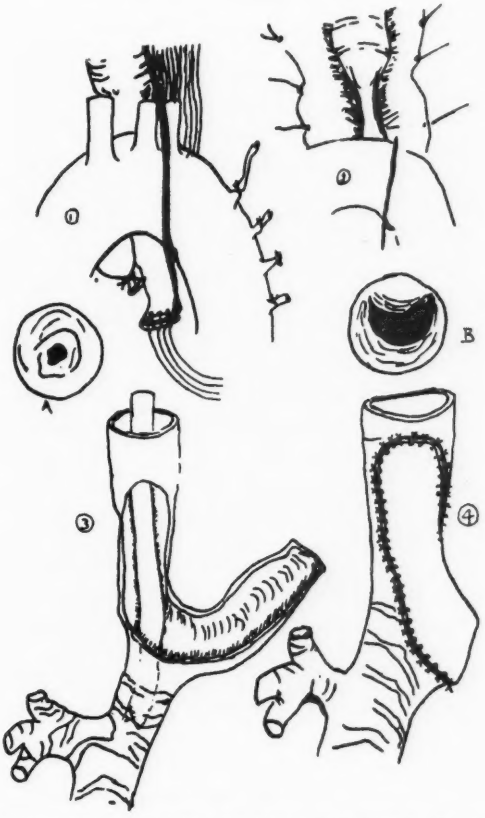

Fig. 6*B*.—Diagram summarizing the lesion and steps in the operation.

The whole of the mind of this patient was concentrated on breathing. An immediate sensation of asphyxia would be precipitated by excitement or talking. She was cyanosed and with forced respiration; stridor was audible from a distance.

Operation: It was thought that a satisfactory inlay could be provided by a pedicle graft of healthy living bronchial stem on the left side across the stenosis. The operation had been carried out under post-mortem conditions where details of surgical technique and anesthesia had been elaborated.

The left chest was opened under local anesthesia (Dr. Watt) through the original thoracoplasty incision. The lung was dissected free, excised at the stenosis, and the long bronchial stump sutured. The loops of the sutures were left uncut, so that it was possible for them to be passed under the aortic arch after this had been mobilized and the bronchus withdrawn above. The mediastinal pleura overlying the trachea was incised and the stenosis recognized as an elongated constriction 1 inch above the aortic arch. The left bronchus and the trachea were incised on the posterolateral aspect right up beyond the stricture and the intratracheal tube advanced down into the right bronchus to maintain respiration. The inlay of the bronchial flap into the trachea and across the stricture was accomplished by tying previously placed everting mattress sutures. These were reinforced by interrupted nylon sutures placed at intervals round the pedicle. The mediastinal pleura was sutured and the chest closed with underwater drainage to allow the negative intrathoracic pressure to expand the graft (Fig. 6*B*).

At postoperative bronchoscopy, a crescentic tracheal lumen was visualized and the bronchoscope was passed beyond with ease. During the first forty-eight hours, the patient was nursed in an oxygen tent. She gained strength rapidly and convalescence was uneventful. Nutrition improved with a 10-pound gain in weight in the first two weeks after operation (Fig. 6*C*).

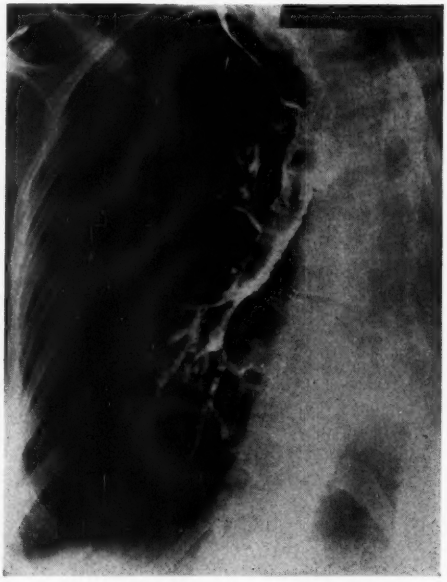

Fig. 6*C*.—One year after left pneumonectomy and restoration by a living graft of the left stem bronchus.

The patient's present state, June, 1955, two years following operation, was recorded as follows: "The lumen in the trachea in the region of the stenosis is normal except for a rounded bulge or dimple where the left bronchus has been drawn upward to provide an inlay. The patient is well and working."

Discussion.—In each case presented, reconstruction has been possible without interruption of the trachea.

A patch of lung was found to provide satisfactory closure without encroachment on the lumen (Case 3), but this expedient has now been superseded by the use of a wire mesh prosthesis covered by autogenous dermis graft

which is molded as a reinforced patch onto the intratracheal tube so as to overlap the defect. Epithelization of the tracheal lumen is accomplished by regeneration of the mucosa over the wire mesh. Wire-supported dermis graft (Gebauer) is just as effective. For localized constrictions, resection and anastomosis has been practiced successfully. Bearing in mind that the defect is much greater after division and release of the stricture, the maintenance of the ends in approximation posteriorly as was done in Case 4 may be found advantageous.

The principle of reimplantation of the bronchus to the trachea across this stricture, akin to a Finney pyloroplasty, has been successfully applied by Gebauer (1953).

Fig. 7.—Post-mortem specimen of tracheobronchial tree of pig removed three months after excision of the tracheal bifurcation and reconstruction performed under hypothermia at 80° F. The repair is almost perfect.

The cure of a long tracheal stenosis was accomplished by insertion of a living bronchial graft (Case 5), a procedure which was later found to have been employed unsuccessfully, but recommended for clinical trial by Kergin (1952).

Complete excision of the segments and restoration of the continuity has been accomplished by plastic prosthesis, by Grindlay, Claggett, and Moersch (1948), and Craig and associates (1949); by supported autografts of fascia (Belsey, 1946; Rob and Bateman, 1949); and, of dermis (Gebauer, 1950).

Direct suture is facilitated by approximating the ends with previously placed wire tension sutures after careful mobilization above and below. The formation of polypoid granulomas is avoided by using multistrand wire and fine plaited nylon sutures and everting the edges as much as possible.

Reconstitution by a permanent prosthesis is to be avoided if possible, owing to the danger of late dislocation of the prosthesis from its bed of scar tissue, and subsequent tracheal stenosis in this site, as experienced by Craig and colleagues (1951), but it has been suggested as an initial treatment in operations involving extensive obstruction of the trachea by a new growth and later replaced by a well-supported dermis graft, Gebauer (1951).

Resection of the bifurcation and reconstitution of the trachea has been worked out in the cadaver and successfully performed under hypothermia at 80° F. on a pig. Oxygen was delivered by means of an intratracheal tube in the usual manner until the right chest was opened. By dividing and cannulating the right bronchus and connecting this to a separate anesthetic machine, temporary oxygenation was maintained, while division of the trachea, together with the bifurcation, was accomplished and the upper intratracheal tube advanced into the left main bronchus. After mobilization and approximation of the left bronchus to the trachea, the cannula was removed from the right bronchus which was then sutured to the left in a double-barrelled manner, and both in turn sutured to the trachea (Fig. 7).

It is considered that in such a special case, deliberate surgery will be found possible under hypothermia and the harmful effects of suboxygenation on the respiratory and vasomotor centers avoided.

MAIN BRONCHI

Opportunities for conservative surgery are few, and only present as localized benign obstructive lesions in which the peripheral bronchial tree is undamaged. Such conditions may result from adenoma or stricture and also from rare cases of malignancy in which adequate excision of the tumor combined with conservation of a healthy lobe is desirable owing to limited respiratory reserve.

CASE 6.—M. McK., 56 years old, housewife, was admitted on July 10, 1954, complaining of wheeze and recurrent episodes of fever over a period of seven years following the diagnosis of pulmonary tuberculosis which were relieved by coughing up large amounts of mucopus.

She was treated for twelve months with streptomycin and para-aminosalicylic acid. The sputum was converted and has remained consistently negative.

At bronchoscopy (Dr. C. McDowell), the left main-stem bronchus, 1.5 cm. from its origin, was shown to end in a firm, smooth, fibrous stenosis 2 mm. in diameter. The presence of a localized stenosis, 1 cm. below the carina, was confirmed by a left bronchogram, the bronchial lumen widening below to connect with the normal left upper lobe. The lower lobe bronchus was completely stenosed (Fig. 8*A*).

At operation, performed July 29, 1954, the left lower lobe was completely collapsed beyond the bronchostenosis and the presence of a further stricture in the left stem, unsupported by cartilaginous rings, verified 3.5 cm. proximal to the upper lobe bronchus.

It was thought possible to perform lower lobectomy of the collapsed and bronchiectatic lower lobe and to conserve the upper lobe by a plastic operation on the main bronchus. After lower lobectomy, the open left stem bronchus was incised posteriorly upward beyond

Fig. 8*A*.—Case 6 (M. McK.). Tuberculous stenosis of left stem bronchus (partial) and of the left lower lobe bronchus (complete). Bronchogram before operation.

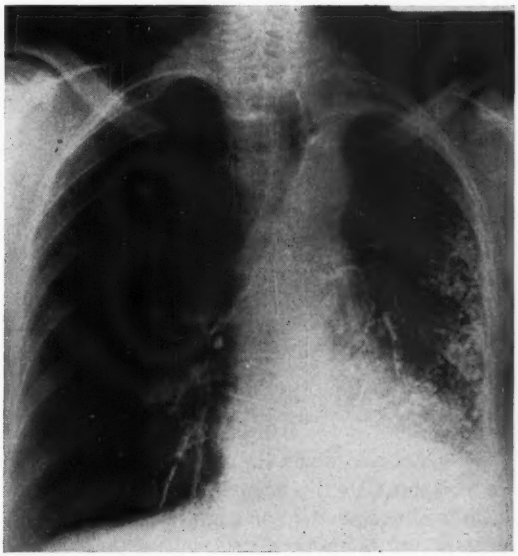

Fig. 8*B*.—After left lower lobe lobectomy and plastic reconstruction of the left stem bronchus.

the stricture and lateral circumferential incisions made to expose the full bronchial lumen. By strong No. 4-0 silk sutures, the upper lobe bronchus was made to lie in continuity with the stem bronchus and the stricture, and the suture line was completed with fine nylon sutures (Figs. 8*B* and 8*C*).

At postoperative bronchoscopy, the lumen was shown to be about ¾ cm. in diameter, and seven months later, a satisfactory lumen was demonstrated by bronchogram. On macroscopic examination of the excised specimen, there was gross bronchiectasis of the fibrotic airless lower lobe which was covered on its surface by shaggy pleura. Advanced bronchiectasis with tuberculous involvement of the lung parenchyma was confirmed by histologic examination.

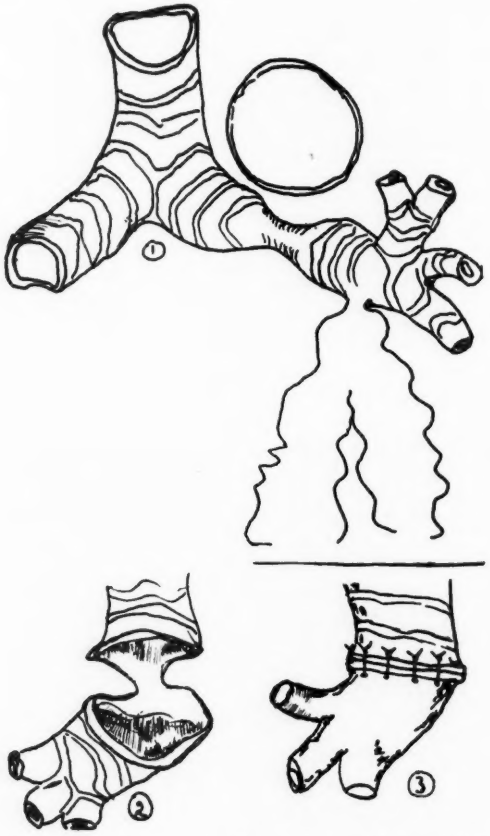

Fig. 8*C*.—Diagram summarizing the preoperative findings and the details of the operation.

Comment: The operation was complicated by small fibrotic caseating glands, so densely adherent to the bronchi and pulmonary artery that perforations were made in the main stem and lingular branches of the artery during dissection, necessitating temporary clamping of the main artery for bloodless suture. It is probable that these caseating lymphatic glands were the initial cause of the bronchial tuberculosis and stricture.

Preliminary lobectomy, conserving as much bronchial tissue as possible, was helpful.

The preliminary placing of stout silk sutures between the upper lobe bronchus and the stem bronchus above the stenosis, and also the manual elevation of the lobe and its bronchial stem taking the tension as the sutures were tied, enabled the procedure to be performed when otherwise it would have been difficult, obscured as it was by the aortic arch.

Discussion: If the local disease is benign and the peripheral lung tissue is healthy, resection and anastomosis are desirable. Operative mishaps in which the bronchus is inadvertently divided so as to exclude or narrow the entrance to a healthy lobe should be repaired immediately to forestall the otherwise most unhappy sequelae of collapse, pneumonitis, and empyema (Fig. 9).

Fig. 9.—Right upper lobe bronchus of pig removed 3 months after complete section and resuture showing complete normal healing without narrowing of the lumen.

Traumatic bronchial injuries may be confirmed bronchoscopically and urgent operation undertaken to restore continuity. Even at a late stage when the disrupted ends have become buried in scar tissue, a healthy lobe may be restored by anastomosis of the divided bronchi.

A note of caution is sounded in dealing with benign tumors of the bronchus for, in our series of cases, there has been bronchiectasis and suppurative changes peripheral to the obstructive lesion in all. In one case, there were involved glands and the patient died of secondary deposits within two years. In another case, seemingly ideal for local treatment, the lobe had to be removed,

after bronchotomy with resection of the tumor and its pedicle, as it could not be inflated. The operation specimen was shown to be partially destroyed by bronchiectasis and emphysema and the excised tumor was identified as a low-grade malignant cylindroma.

A classic reconstruction for benign tumor has been reported by Officer Brown (1954). After local excision of an adenoma involving the bronchus to the upper lobe, the apical segment of the lower lobe, and the basal segments, reconstruction of the entire lung was successfully accomplished by suturing the divided distal bronchi together as a multibarrelled unit which was then anastomosed with the left main bronchus.

It has been shown on the cadaver that radical lobectomy of both upper and lower lobes, so as to include a large bronchial segment together with the involved lymphatic glands extending into the mediastinum, can be accomplished if local conditions are favorable and the overriding necessity of preservation of pulmonary tissue is present.

Experience has confirmed bronchial resection and anastomosis to be much more successful than repair by graft. Retraction of the divided ends may be prevented by the plastic procedure described in Case 4. If actual resection and reanastomosis is required, it has been found of considerable help experimentally to have a wide exposure of the bronchi, to have adequate control of the ends by traction sutures before division of the bronchus, to keep close to the lesion, and to place all the difficult sutures in position before any one is tied. For complicated reconstruction, the formation of a multibarrelled anastomosis is likely to be helpful. In cases of disproportion, a "Z" plasty in the smaller bronchus, as described by Holman and Hahn (1953), for dealing with this problem in blood vessels, has been of value in the laboratory.

SUMMARY

The indications for reparative surgery in dealing with lesions of the trachea in its cervical and thoracic parts, and of the main bronchi, has been discussed. Details of cases, illustrating the subject matter and also developmental surgical procedures carried out to investigate some controversial problems, have been included in the text.

I wish to thank members of the Chest Unit for permission to discuss the patients and for their help in the management of them.

Case 3 was operated upon by Mr. Douglas Robb assisted by the author.

I acknowledge with pleasure the skill of Dr. J. R. Hinds in making the outline drawings, the help of Dr. Chisholm McDowell with the manuscript, the industry of Miss Catherine Tibbles of the Central Medical Library, the painstaking photography of Mr. Burge, and the patience of Miss Kerkin in the typing of the manuscript.

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POSTURAL CYANOSIS AND ANGINA PECTORIS FOLLOWING PNEUMONECTOMY: RELIEF BY CLOSURE OF AN INTERATRIAL SEPTAL DEFECT

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THIS is a report of an unusual postpneumonectomy complication, the development of an interatrial right-to-left shunt. The story is even more unusual in that cyanosis and angina pectoris developed only when the patient was sitting or standing; recumbency brought relief. Before this abnormal communication was recognized and closed surgically, with almost complete alleviation of the patient's symptoms, a variety of clinical and laboratory observations, correct in themselves, had inspired some incorrect diagnoses. We believe that it will be useful to present not only the case report but also an account of our early hesitant and faulty diagnoses. Our difficulties are well described by John Hayward when he wrote, "For who is so deaf or so blind as he that willfully will neither hear nor see?"

CASE REPORT

The patient, a 60-year-old man, was admitted to the Hospital of the University of Pennsylvania on July 3, 1950, because of repeated episodes of hemoptysis during a 2-day period. He stated that he had been in good health except for several attacks of renal colic and an episode of epigastric pain fifteen years before that had been attributed to a duodenal ulcer. Chest x-rays, bronchoscopic examination, and microscopic study of the bronchial secretions failed to reveal the cause of the pulmonary bleeding. He was followed as an outpatient, however, with periodic physical examinations and chest x-rays until July, 1952, when a definite lesion was found by x-ray in the upper lobe of the right lung.

He was then admitted to the University Hospital for thoracotomy. At that time, he gave no history of dyspnea, chest pain, cyanosis, or ankle edema. On physical examination, no cyanosis was noted nor was there any clubbing of the fingers or toes. The blood pressure was 130/80. No cardiac murmurs were heard. The anteroposterior chest diameter was slightly increased, suggesting a minimal degree of emphysema. Fluoroscopy of the chest revealed no cardiac enlargement. An electrocardiogram was within normal limits. Numerous hemoglobin determinations ranged between 14.5 and 16.2 Gm. The highest red blood cell count was 4.6 million. Shortly after admission, a thoracotomy was performed. A 3 cm. mass in the right upper lobe was found, which proved on frozen section to be a squamous-cell carcinoma. A right pneumonectomy was done. No evidence of metastasis was found in twelve hilar lymph nodes. The postoperative course was uneventful except that on the sixth day he noticed anterior chest pain; it was thought to be related to the incision. He was discharged on the fourteenth postoperative day.

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During the next fourteen months he was readmitted to the hospital five different times. His chief complaint on each admission was dyspnea associated with epigastric pain; the latter was not relieved by food or alkali. At first these symptoms appeared only during the day. Later he noticed that the pain and dyspnea occurred only when he was sitting or standing, and disappeared completely when he was horizontal in bed. Eventually, the severity of the symptoms had become so great that he voluntarily remained in bed most of the time.

On the first readmission, one month after the lung resection, the physical examination had showed no changes beyond those connected with the shift to the right of the mediastinal structures and the usual hydrothorax following pneumonectomy. No cyanosis was observed. A gastrointestinal series was interpreted as indicative of an active duodenal ulcer. In spite of the atypical pattern of the pain, his symptoms were thought to be due to the ulcer. He was therefore discharged on a strict Sippy regimen.

On the second readmission, two months later, it was thought that the pain and dyspnea, which had not been relieved by the Sippy regimen, might be related to a decrease in pulmonary reserve, resulting from pneumonectomy. One observer at this time noted "a peculiar, blue color to his fingernails," but another of his physicians stated that "no cyanosis was present." Limited pulmonary function studies showed a vital capacity of 2,060 ml., an inspiratory capacity of 1,280 ml., expiratory reserve of 780 ml., maximal breathing capacity of 60 L. per minute, and some degree of nonuniform gas distribution. An ear oximeter* showed some increase in the arterial oxygen saturation following two minutes on a treadmill at two miles per hour. During this exercise the patient developed severe dyspnea and chest pain. Since the studies showed fairly good ventilatory function for a 60-year-old man with one lung, it was thought that the reduced exercise tolerance might be due, at least in part, to cardiac insufficiency. The diagnosis on discharge was dyspnea with "a marked functional component." No explanation of the cyanosis noted by one observer was offered.

On the third readmission, in January of 1953, the severity of the dyspnea and pain on standing or sitting made him stay in bed almost constantly, but the physical findings remained unchanged. No cyanosis was observed by anyone. Numerous studies were made: (1) Gastrointestinal x-rays and esophagoscopy revealed no evidence of hiatal hernia. The old duodenal ulcer appeared unchanged from the previous examination. (2) Bronchoscopic examination and chest x-ray showed no signs of a malignant process nor any other possible cause for the pain. (3) Electrocardiogram showed no evidence of myocardial abnormality. Nitroglycerine did not relieve the pain. (4) The use of pneumoperitoneum in an effort to increase the ventilatory efficiency did not relieve the symptoms. (5) Oximetric studies following the inhalation of 100 per cent oxygen showed a 6 per cent rise in the arterial oxygen saturation; minimal exercise was associated with a 2 per cent fall in the arterial oxygen saturation. These results were believed to be due to a decreased pulmonary reserve. (6) A manometric analysis of arterial blood, drawn when the patient was recumbent, showed an oxygen saturation of 94 per cent. On March 29, 1953, the patient was again discharged, this time without diagnosis. Most of the observers felt that his main problem was psychiatric, in which opinion the psychiatrists concurred. In retrospect, it becomes plain that no studies during this admission were directed toward the cardinal symptom in the patient's history, namely, that the pain and dyspnea were never present when he was recumbent.

On his fourth readmission in August, 1953, one year after pneumonectomy, it was noted again that he was cyanotic. The fingers showed early clubbing. Hemoglobin determinations as high as 18.7 Gm. were recorded; the hematocrit was 55 per cent. Gastrointestinal x-rays were again interpreted as showing an active duodenal ulcer. A Sippy regimen was once more prescribed, and the patient was discharged.

The fifth and last readmission was on Nov. 24, 1953. Again, the history of dyspnea and pain, except when he was lying flat, was unchanged. Some observers at this time

*The oximeter used was a Millikan type, which records *changes* in oxygen saturation with reasonable accuracy, but does not measure *absolute* values for saturation unless first "set" to agree with values obtained by direct measurement on arterial blood samples.

believed that he was cyanotic; others that he was not. The hemoglobin was recorded as 17.2 Gm., but otherwise the basic laboratory studies were within normal limits. An electrocardiogram showed questionable evidence of "old posterior wall damage." Members of the ward staff were now aware of the relation of the patient's symptoms to his posture; nevertheless, studies continued to be done with the patient recumbent. Circulation times of 22 and 35 seconds were reported, all done with the patient lying flat in bed.

Pulmonary function studies were requested again but only screening procedures were considered necessary. Fortunately, three things now took place: First, the studies in the Pulmonary Function Section are done routinely with the patient in a semisitting position. Second, the patient's cyanosis in this position became obvious to all observers. Third, inhalation of oxygen increased the oximeter reading only 10 per cent and did not relieve the patient's cyanosis. It now became essential to determine the absolute values for arterial O_2 saturation by manometric determinations on arterial blood samples: while the patient was breathing air, the arterial O_2 saturation was 61 per cent; when breathing oxygen, it rose to only 66 per cent. Since, in the experience of the Pulmonary Function Section, the failure of inhalation of oxygen to increase saturation to 100 per cent should be explained only by the existence of a venous to arterial shunt,* they recommended that angiocardiograms and cardiac catheterization be done to determine whether this shunt was located in the lung or in the heart. Thus, in December of 1953, one year and five admissions after the patient's first complaint following pneumonectomy, the diagnosis of the right-to-left shunt was made.

Quickly, however, it was discarded because an angiocardiogram, done with the patient recumbent, showed only questionable evidence of a small left-to-right shunt at the auricular level. Final "proof" that there could be no venous to arterial shunt came when cardiac catheterization, done with the patient recumbent, showed an arterial saturation of 94 per cent. The Pulmonary Function Section, indeed, was suspected of having drawn and analyzed venous rather than arterial blood. Several days later, stung by this accusation, the Pulmonary Function Section again withdrew blood from the semireclining patient from a vessel connected to a mercury manometer that registered a blood pressure of 110 mm. Hg, i.e., a vessel that could be assumed with some confidence to be an artery. When the patient breathed air, the saturation was 65 per cent and when he breathed oxygen, the saturation increased to 78 per cent.

Discussion between members of the Cardiovascular and the Pulmonary Function Sections now became sufficiently heated to result in the performance of three really critical studies:

1. *Inhalation of low oxygen concentration.* With the patient recumbent and asymptomatic, the pain and dyspnea were reproduced by the inhalation of 10 per cent oxygen; the pain was relieved within two minutes after he breathed 100 per cent oxygen.

2. *Oximetric studies with the patient in various positions.* There was a marked rise in oxygen saturation when the patient lay down after standing. In addition, the arterial saturation was definitely and consistently higher when the patient lay on the right side rather than on the left.

3. *Circulation times, with the patient recumbent and at a 45-degree tilt.* An ear oximeter was used to follow the color changes following the injection of Evans blue dye through a catheter into the pulmonary artery, the right ventricle, and the right auricle. The results were as follows: At a 45-degree tilt, the circulation times were—pulmonary artery to ear, 13 seconds; right ventricle to ear, 14 seconds; right auricle to ear, 6 seconds. Recumbent, a very small amount of dye was detected at 6 seconds after the injection of the dye into the right auricle, while the majority of the dye reached the ear 10 seconds later.

*In a study of more than 200 patients with anoxemia owing to a variety of causes, inhalation of 100 per cent oxygen always raised arterial oxygen saturation and dissolved oxygen content to maximal values unless a venous to arterial shunt (pulmonary hemangioma, atelectasis, or intercardiac right-to-left shunt) was present. A high concentration of oxygen in the alveolar gas, effected by inhalation of oxygen, always relieved the anoxemia caused by pulmonary disorders, whether due to hypoventilation, uneven distribution, or impaired diffusion.

Thus, the final diagnosis was made that, following pneumonectomy, a venous to arterial shunt at the level of the right atrium had developed, which was inconsequential when the patient was recumbent. However, when the patient was erect the shunt increased in size and caused sufficient hypoxia to produce anginal type of pain.

On Jan. 13, 1954, a thoracotomy was performed. On exploring the right atrium with the index finger inserted through the atrial appendage, an interatrial defect slightly larger than the finger was found. The defect, which appeared to be a foramen ovale type, was located behind and slightly superior to the orifice of the superior vena cava. By passing two silk sutures through the wall of the atrium, the valve of the foramen ovale, and the interatrial septum, it was possible to close the defect completely when the sutures were tied. Postoperatively, the patient made an excellent recovery. Now, twenty-two months later, he is still acyanotic and ambulatory. He feels a dull epigastric sensation, but that is far different from the severe anginal pain about which he had previously complained. The arterial oxygen saturation, while breathing air, is 97 per cent in any posture, whether measured by the Pulmonary Function or the Cardiovascular Sections, and, while breathing 100 per cent oxygen, the arterial oxygen saturation and the dissolved oxygen reach maximal values.

DISCUSSION

Recently, Wright and his associates[1] reported the case of a 31-year-old man in whom "orthostatic" dyspnea and cyanosis appeared subsequent to a traumatic injury of the chest. Catheterization findings and direct palpation of the right atrium at thoracotomy led them to the conclusion that their patient had Ebstein's malformation; the atrial septal defect was closed, and the symptoms disappeared. Although our patient's somewhat similar symptoms also followed traumatic injury of the chest, though of a different type (pneumonectomy), it was not possible, either on the basis of catheterization findings or by direct palpation of the atrium at the time of surgery, to implicate Ebstein's malformation. It is our conclusion that the venous to arterial shunt in our patient probably occurred because of a simple foramen ovale type of defect.

Cyanosis occurring only in the sitting or erect position in patients with intracardiac shunts may be caused by several mechanisms:

1. *A change in the pressure gradient sufficient to produce a right-to-left shunt or to increase the magnitude of an existing shunt.* This physiologic state has been reported by Hamilton[2] in a patient with tetralogy of Fallot resulting from a marked drop in systemic arterial pressure. It might also occur as the result of an increase in right heart pressures owing to increased resistance to flow through the pulmonary vascular bed. It was not possible to demonstrate that either of these conditions was present in our patient. The systemic arterial pressure did not change appreciably when he was in the erect position, nor could any elevation of right heart pressures be detected when he changed from the recumbent to a 45-degree semisitting position. It is possible, however, that a pressure gradient developed in our patient when he was in the erect position because of the usual shift of the mediastinal structures after pneumonectomy which, in this patient, led to a change in the relative positions of the two atria. Evidence in support of this possibility is that a higher degree of arterial saturation was found when he was in a right lateral position than when in a left lateral position. Indeed, in the left lateral position, a pressure gradient favorable to the shunting of blood from right to left may well have developed on the basis of hydrostatic factors alone.

2. *A decreased venous oxygen saturation.* If such a condition existed, no increase in the volume flow through the shunt need be postulated, since the increased cyanosis could be due merely to the mixture of arterial blood with venous blood of greater unsaturation flowing in constant amounts through the shunt. It has been shown recently[3] that this mechanism may be the cause of the increased cyanosis seen in patients with tetralogy of Fallot when in an erect position. In the patient reported by Wright and colleagues,[1] the size of the shunt and the degree of cyanosis were not closely related. In our patient, however, the ear oximeter studies using Evans blue dye strongly suggest that most of the cyanosis was due to an increase in the actual degree of the venous to arterial shunt whenever he sat up.

The failure of all but one of our patient's physicians to detect the early signs of cyanosis raises the following points: (1) The clinical diagnosis of arterial anoxemia by visual observation of cyanosis is uncertain, for the ability to recognize blueness varies greatly,[4] (2) a well-calibrated, absolute reading oximeter may be required to detect anoxemia unless an arterial blood sample is drawn and analyzed, and (3) incomplete pulmonary function studies may be misleading; therefore, a complete arterial blood gas analysis should be done whenever screening procedures give a questionable diagnosis.

In retrospect, it is hard to understand why so many of us for so long paid no attention to the patient's history of pain and dyspnea in connection with his position. This reluctance to believe what we heard and saw was due to our desire to accept an ordinary explanation as the basis of the patient's symptoms and a certain lack of imagination with which we might have postulated a complication of this type resulting from pneumonectomy.

SUMMARY

1. A case is reported in which a 60-year-old male patient developed a venous-arterial shunt through an interatrial septal defect following pneumonectomy performed because of carcinoma of the right lung.

2. The changes associated with the atrial septal defect resulted in dyspnea, epigastric pain, and cyanosis in the sitting and standing positions only; they disappeared on recumbency.

3. Hypoxia was found to occur only in the sitting or standing position and was responsible for the dyspnea, cyanosis, and anginal pain.

4. The atrial defect was surgically closed with almost complete alleviation of the patient's symptoms.

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RESECTION AND ORLON GRAFT OF MULTIPLE AORTIC ANEURYSMS DUE TO TRAUMA

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TWO major problems arise from the cross-clamping of the thoracic aorta during resection and graft replacement. They are a rapid dilatation and failure of the left ventricle, and ischemic damage to distal organ systems.

Hypothermia is a means by which the cardiac output can be reduced and the distal refrigerated tissue has an increased tolerance to ischemia.[1]

DeBakey and Cooley (1954)[2] and Julian and associates (1953)[3] have reported two successful resections and homografting of traumatic thoracic aneurysms under hypothermia. An additional successful case of traumatic multiple aneurysms of the thoracic aorta treated by resection and orlon graft with hypothermia is presented.

CASE REPORT

A 31-year-old white man was injured by a land mine explosion in 1943 during World War II. He suffered severe contusion of the left chest without any external wounds and was hospitalized for eight months. Since discharge from the service he has complained of fatigue, weakness, exertional dyspnea, and left chest pain radiating posteriorly between the shoulders. These symptoms increased in severity during the last year to such an extent that he sought medical attention. Physical examination was negative except for a diminished radial pulse in the left arm. The blood pressure was 110 systolic and 70 diastolic mm. Hg. The serology was negative. Complete blood count, urinalysis, and blood chemistry studies were within normal limits. An electrocardiogram was normal.

Roentgenologic and fluoroscopic findings confirmed the diagnosis of an aneurysm of the descending arch and thoracic aorta.

Operation: On Sept. 9, 1955, thoracotomy was done with endotracheal anesthesia. Anesthetic agents consisted of Pentothal sodium, oxygen-ether, and general hypothermia to 28° C. Two aneurysms were present. The superior one arose 2 cm. below the origin of the left subclavian artery and extended posteriorly into the vertebral gutter and measured 6 by 6 cm. Immediately below this aneurysm the aorta was of normal caliber for a distance of 1.5 cm. Another aneurysm arose below this level and extended medially into the mediastinum and measured 4 by 4 cm. This medial aneurysm compressed the left main-stem bronchus (Fig. 1). The aorta above and below the aneurysm was normal.

The distal thoracic arch of the aorta and the left subclavian artery were occluded with a DeBakey clamp. The distal descending aorta was then cross-clamped. The rectal temperature was 28° C. when the aorta was cross-clamped. The blood pressure prior to occlusion was 60 systolic and 40 diastolic mm. Hg and rose to a level of 120 systolic and 60 diastolic mm. Hg during the 50 minutes of complete occlusion. The multiple aneurysms were excised and the segmental intercostal arteries were ligated as they were encountered. A seamless orlon prosthetic graft 12 cm. long was sutured into the aortic defect (Fig. 2). A continuous No. 4-0 black arterial silk suture was used. The distal clamp was removed first, allowing the orlon graft to distend and fill the mesh of the orlon with fibrin.

The proximal occluding aortic clamp was gradually released over a 25-minute period. The blood pressure at the end of this time was 60 systolic and 40 diastolic mm. Hg. One thousand cubic centimeters of whole blood was given for replacement. The lungs were

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expanded and catheter chest drainage instituted. The patient was rewarmed to 96° F. and returned to the recovery room. Blood pressure at this time was 120 systolic and 60 diastolic mm. Hg.

Pathology: Sections of the excised aneurysms showed hyalinization, calcification, and fragmentation of the elastic fibers. Many areas of the aneurysms were thin and elastic fibers were absent.

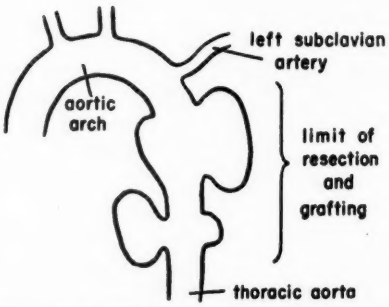

Fig. 1.—Diagram of multiple thoracic aneurysms due to trauma.

Fig. 2.—Surgical defect of descending thoracic aorta spanned with a seamless orlon graft.

The postoperative course was uneventful and the patient was discharged on the tenth postoperative day to another hospital to convalesce for an additional two weeks. There were no cardiac or neurological complications.

DISCUSSION

Lam and Aram (1951)[4] reported the homografting of a syphilitic thoracic aneurysm. The aneurysmal sac was left in place and the patient died in three months from a mediastinal abscess with secondary hemorrhage.

Brock and Graham (1952)[5] successfully resected and homografted an aneurysm associated with coarctation. The presence of adequate collateral circulation in coarctation markedly differentiates the effect of thoracic aorta occlusion from that of an aneurysm.

DeBakey and Cooley (1953)[6] and Gwathmey and Thompson (1955)[7] successfully resected and replaced a fusiform arteriosclerotic thoracic aneurysm with a homograft. These two operations were done without hypothermia. One cannot predict preoperatively the reserve of the heart to withstand the work load incident to aortic occlusion or ischemic damage to distal organ systems.

In order to circumvent the complications of acute aortic cross-clamping, intraluminal, or external shunts along with partial venous inflow occlusion have been done.[8] Hypothermia seems a more simple method. The depth of hypothermia does not have to be extreme. A range of 28° C. to 30° C. protects the heart against overloading and distal organ systems against ischemia.

SUMMARY

The successful repair of multiple traumatic thoracic aneurysms of the thoracic aorta is reported. Under hypothermia, a seamless orlon graft was used to graft the thoracic defect.

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LUNG ABSCESS IN INDIA

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MUCH of the knowledge regarding the etiological factors of lung abscess has been derived from the experimental work of Brock (1942) and Wig (1951). Allen (1928) has contributed a great deal to the understanding of the pathology of lung abscess.

The advent of sulfonamides and antibiotics has changed the outlook in this malady. It appears that the time has come when the opinion expressed by Smith (1948), Klepser and Davis (1952), and Brock (1952) should be reconsidered in the light of the experience gained in recent years. After a critical study of the papers of Jewett and Dimond (1950), Metras and Charpin (1954), Fox and co-workers (1954), and Gittens and Mihaly (1954), the much advocated surgical procedures even in acute lung abscesses seem to be a little out of place. Acute lung abscesses respond easily to the antibiotics.

In the present communication an attempt will be made to discuss the role of antibiotics in the management of lung abscess.

METHODS, MATERIAL, AND RESULTS

The present study includes an analysis of 60 cases of lung abscess, 31 of which were studied at Jaya Aroyga Hospital, Gwalior, from March, 1950, to April, 1953, while 29 cases were studied at the tuberculosis clinic, Delhi, from April, 1953, to August, 1955.

Only those cases have been included in which a specific cause could not be found. Lung abscesses secondary to neoplasm, amebiosis, bronchiectasis, and foreign body have been excluded.

Sex: Out of 60 patients, 52 were males, and 8 females.

Age: Table I shows the age distribution.

TABLE I. THE AGE DISTRIBUTION

AGE (YEARS)	NUMBER OF CASES
Under 10	3
11-20	8
21-30	11
31-40	11
41-50	16
51-60	11

Etiology: No case was encountered following dental extraction, operations on the respiratory tract, or as a postoperative complication. In 22 cases,

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dental sepsis was a prominent feature, in another 15 cases, there were coryza and catarrh of the upper respiratory passages immediately preceding the lung abscess. In 23 cases, no definite etiological factor could be found.

The lobar distribution is presented in Table II.

TABLE II. THE LOBAR DISTRIBUTION

LOCATION	NUMBER OF CASES
Right upper lobe	20
Right middle lobe	5
Right lower lobe	18
Left upper lobe	9
Left lower lobe	8

In only 20 cases, in addition to posteroanterior views, lateral skiagrams of the chest were taken also to find the segmental distribution. The results are shown in Table III.

TABLE III. THE SEGMENTAL DISTRIBUTION

SEGMENTS	RIGHT SIDE	LEFT SIDE
Upper Lobe		
Anterior	-	2
Posterior	5	-
Both segments	1	-
Lower Lobe		
Apical	6	3
Anterior basal	1	-
Posterior basal	-	1
Middle lobe	1	-

The relation of the duration of the disease and the effect of therapy is presented in Table IV.

TABLE IV. THE EFFECT OF THERAPY AND DURATION OF THE DISEASE

DURATION	NUMBER OF PATIENTS	DIED	CHRONIC	CURED
Six weeks	41	3	5	33
Over six weeks	19	-	11	8

In the evaluation, the patients who have been treated with antibiotics and have been followed for at least three months have been included. The results are tabulated in Table V. All patients received supportive measures such as proper postural drainage and necessary expectorants.

TABLE V. EFFECT OF TREATMENT

GROUPS	NUMBER OF CASES	DIED	CHRONIC	CURED
Group 1				
Penicillin and sulfonamides	49	3	11 + 10* + 8†	17
Group 2				
Penicillin and deep x-rays	10*	-	3	7
Group 3				
Penicillin, high doses	19 (11 + 8)†	-	2 + 6‡	11
Group 4				
Tetracycline	6‡	-	-	6
	60	3	16	41

The symbols *, † and ‡ represent the number of cases transferred from one group to another when one line of therapy failed, each pair of symbols referring to the same cases.

GROUP 1. Forty-nine patients were treated with penicillin, 2 to 4 lacs* daily, in divided doses for a total of 40 to 60 lacs and, in addition, sulfadiazine, about 30 Gm., was administered also. After about three weeks, clinical and roentgenologic studies were undertaken to evaluate the results. Seventeen patients were completely cured clinically and roentgenologically, while in 11 there was no improvement, and another 18 showed clinical improvement without any significant change in roentgenologic shadows. This represents a cure rate of about 34 per cent. Bronchographic examination was carried out in 2 cases. In 1, there was classical saccular bronchiectasis while in the other there was a minor degree of cylindrical bronchiectasis.

Fig. 1.—A skiagram of chest, posteroanterior view (K. C., June 6, 1953), which shows a cavity with fluid level 5 by 4 cm. surrounded by homogeneous opacity.

Illustrative case: K. C., 1738/55, a 24-year-old man, reported on June 16, 1953. The patient had had a cold and coryza with rhinitis about three weeks previously. About 2 weeks afterward, he had pain in the right chest and one week later noted fever and cough with profuse foul-smelling expectoration. The past history was not relevant. His occupation was cleaner of petrol trucks. At least twice a week, he had to empty the tank by siphoning the remaining petrol from it. A skiagram of the chest made June 15, 1953 (Fig. 1) showed a cavity with a fluid level of 5 by 4 cm. surrounded by a homogeneous opacity which occupied the posterior segment of the right upper lobe. He was given 60 lacs of procaine penicillin, as 4 lacs daily, which gave him complete clinical cure, but did not clear a 15 per cent loss of radiolucency. Over a follow-up period of two years he has had no complaints. Tomograms made on July 26, 1955, showed small cystlike cavities in the affected segment. Bronchograms, made on Sept. 4, 1955 (Fig. 2), revealed saccular and cystic ectasis of the posterior segment of the upper lobe and apical segment of the right lower lobe.

*A lac represents 100,000 units.

Comments: Probable pathogenesis in this case appears to be infection of the upper respiratory tract and, at the same time, inhalation of the petroleum. The infected material along with the petroleum produced a bronchial embolism leading to an abscess formation. The abscess did not limit itself to the segmental barrier as shown by the cylindrical ectasis of the apical segment of the lower lobe. Further, this extensive bronchiectasis did not produce any signs and symptoms for over two years.

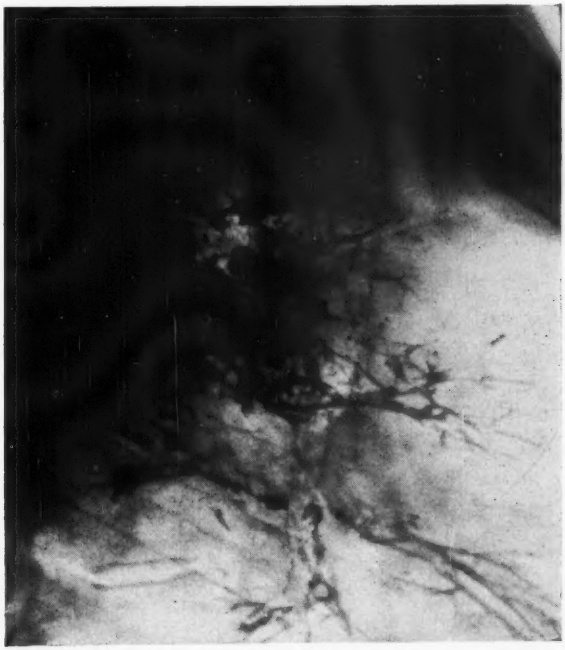

Fig. 2.—A bronchogram, right lateral view (K. C., Sept. 4, 1955), which shows saccular and cystic bronchiestasis.

GROUP 2. As chest surgery was not available in J. A. Hospital, Gwalior, it was decided that the patients who did not show a satisfactory response to penicillin after three weeks should be submitted to a course of deep roentgen ray irradiation to the chest with the idea of producing fibrosis. It must be confessed that this was an empirical therapy. In this group, penicillin was continued for another two weeks and the chest was exposed to deep x-rays to a total of 1,000 gamma units as 100 units daily, alternately on the back and front of the chest. After two weeks, the cases were again reviewed and if the cavity had closed [though slight (10 per cent) loss of radiolucency might persist] with no signs and symptoms, the case was labeled as cured. Hematologic study revealed no adverse effects. Ten patients from Group 1, 1 chronic, and 9 relieved, were submitted to this therapy. There was no change in the chronic lung abscess, but out of the 9 relieved patients, 7 were cured completely

Fig. 3.—A skiagram of chest (M. R., July 5, 1952) which shows a cavity in the right lower lobe.

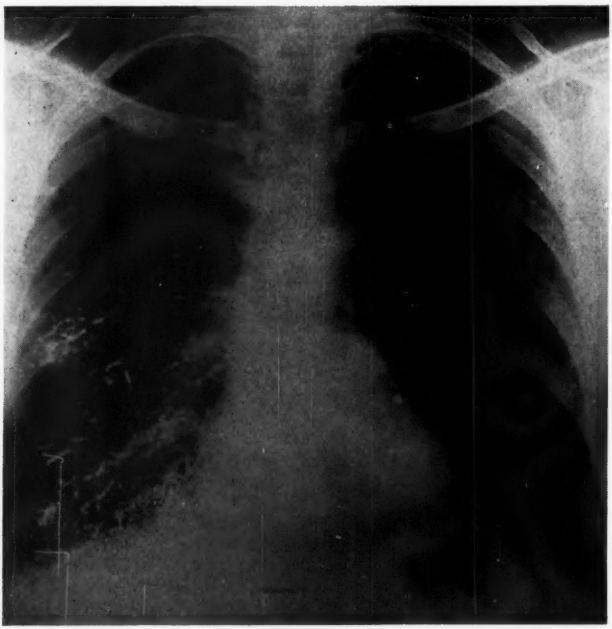

Fig. 4.—Bronchogram (M. R., Sept. 17, 1952). The cavity has disappeared but the contrast medium has not entered the diseased area.

according to the above-mentioned standard. Out of these 7 patients, 3 were submitted to bronchography and in all 3 the contrast medium did not enter the diseased area.

Illustrative case. A man 45-years-old, was admitted to J. A. Hospital, Gwalior, on June 20, 1952, with a history of pyrexia, cough with expectoration, and pain in the right side of the chest of six weeks' duration. Sputum on direct smear and concentration was negative for tubercle bacilli. Roentgenogram of the chest (July 5, 1952; Fig. 3), showed a cavity with a surrounding area of consolidation. He was given 60 lacs of penicillin with 30 Gm. of sulfadiazine. The clinical condition improved but a skiagram of the chest made July 28, 1952, showed no change. He was given another 30 lacs of penicillin and a course of deep roentgen rays. Bronchography (Fig. 4; Sept. 17, 1952) revealed that the cavity had disappeared, and only a slight haziness persisted. The contrast medium did not enter the diseased area.

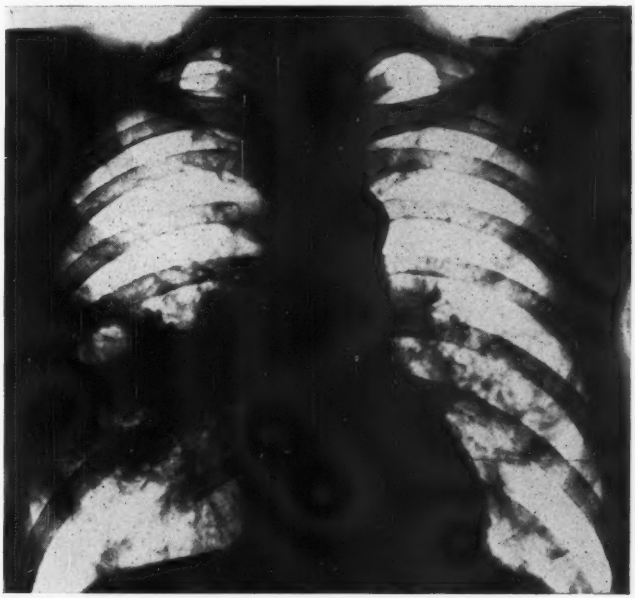

Fig. 5.—A skiagram of the chest, posteroanterior view (N. I., Nov. 26, 1954), shows a cavity 6 by 3.5 cm. in the right lower lobe.

GROUP 3. With past experience and newer concepts it was felt that the dosage of penicillin was very low. It was decided that at least 10 to 20 lacs of penicillin should be given daily. Nineteen cases were submitted to this therapy, 8 of which had already received 40 to 60 lacs of penicillin without much roentgenologic change. Of these, 11 were completely cured, while 8 showed only clinical improvement.

Illustrative Cases.—

CASE 1.—K. L., 931/55, a 30-year-old man, reported with a two-week history of fever and cough with profuse foul-smelling expectoration. He had moderate hemoptysis. A skiagram of the chest made May 14, 1955, showed a cavity 8 by 5.6 cm. in the posterior

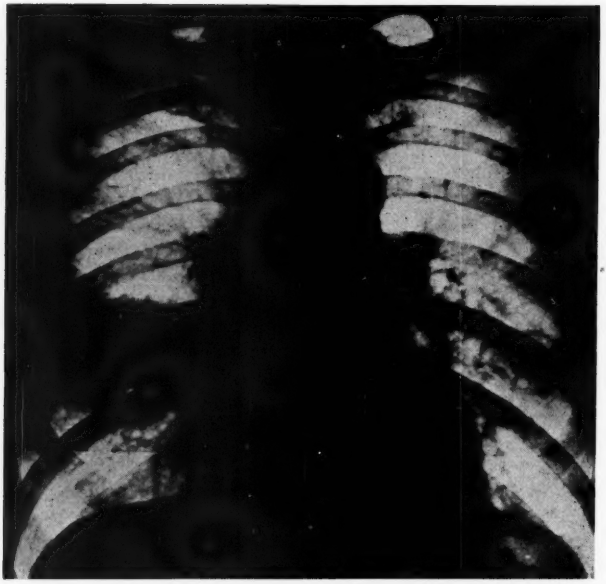

Fig. 6.—A skiagram of the chest, posteroanterior view (N. I., April 6, 1955), shows a homogeneous opacity at the site of cavity, probably an inspissated cavity.

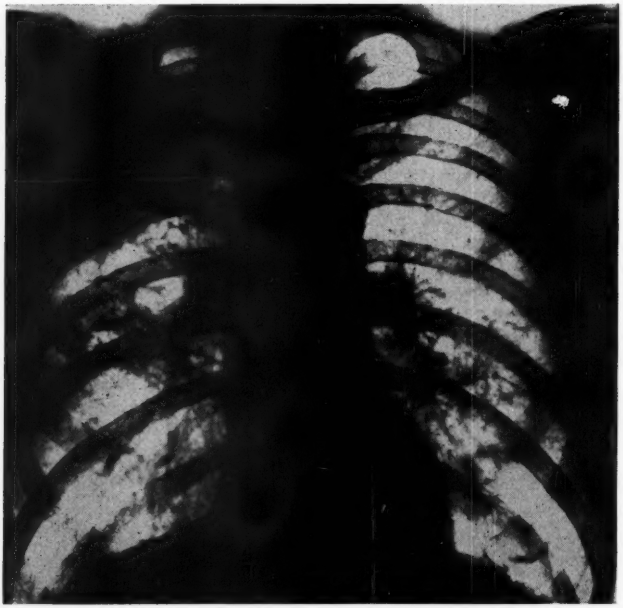

Fig. 7.—A skiagram of the chest, posteroanterior view (N. I., June 30, 1955), reveals a spill-over abscess, right upper lobe. The closed inspissated cavity has been replaced by small cystic shadows.

segment of the left lower lobe. He received 300 lacs of penicillin during a one-month period. Bronchograms made on Aug. 24, 1955, showed two cystlike cavities in the posterior basal segment revealing that two bronchi were communicating with the abscess cavity.

CASE 2.—N. I., 3346/54, a 50-year-old man, reported on Nov. 22, 1954, with a history of three weeks of fever and cough with profuse foul-smelling expectoration. Past history revealed that he had frequent bouts of respiratory infection following an attack of cold and coryza. A skiagram make on Nov. 26, 1954 (Fig. 5), revealed a cavity 6 by 3.5 cm. in the apical segment of right lower lobe. He was given 100 lacs of penicillin for a period of ten days, with complete clinical cure but the cavity persisted. The patient discontinued the treatment and reported again on April 6, 1955, and a skiagram of the chest revealed a homogeneous opacity (Fig. 6), probably an inspissated cavity. Bronchoscopy at this stage revealed that the right bronchus was full of thick secretion and there was some distortion of the bronchial tree. Congestion and swelling of the mucosa with some circumferential stenosis was also present. The apical segment of the lower lobe was completely occluded. Again, the patient disappeared and a checkup on June 30, 1955 (Fig. 7), revealed a spill-over abscess in the right upper zone, the inspissated cavity had been replaced by a small cystlike cavity. The patient migrated to Pakistan at this stage.

Comment: This patient had little radiologic improvement after 100 lacs of penicillin. At one stage, the obstruction was complete in the bronchus due to endobronchial disease and plugging by the thick purulent material leading to the closed inspissated cavity. When the obstruction was relieved, the inspissated cavity was replaced by small cystlike shadows, in addition, he had a spill-over abscess.

Bronchographic examination was carried out in 4 cases, in 2, there was saccular bronchiectasis, in the other 2, there was cylindrical residual dilatation of moderate degree of the affected bronchi.

GROUP 4. It was decided that patients not responding to penicillin should be given broad spectrum antibiotics. We tried about 10 Gm. of tetracycline in divided doses in 6 patients with acute lung abscess with definite cavities. All responded with complete clinical and radiologic cure. Two patients were submitted to bronchographic examination, in 1 a cystlike cavity still persists after one and one-half years, and in the other a minor degree of cylindrical bronchiectasis still persists.

Illustrative case: S. K., 17/54, a 14-year-old girl, reported with a three-week history of fever and cough with profuse foul-smelling expectoration. A previous skiagram of the chest made Feb. 27, 1953, was normal. A skiagram of the chest made Dec. 8, 1953 (Fig. 8), showed a cavity 8 by 6 cm. in the anterior segment of the left upper lobe with a surrounding consolidation. She was given 160 lacs of penicillin over a period of three weeks. The cough and expectoration disappeared but the fever still persisted at 100° F. A skiagram of the chest Jan. 2, 1954 (Fig. 9), showed a cystlike shadow 5.5 by 7 cm. She was given 8 Gm. of Aureomycin (Lederle), the fever came down to normal. A skiagram made on Jan. 16, 1954 (Fig. 10), showed that the cyst had enlarged to 7.5 to 9 cm. A bronchogram made on Feb. 17, 1955 (Fig. 11), showed a cystlike cavity with a minor degree of residual ectasis of the anterior segment of the left upper lobe and lingula.

Comment: This case is interesting due to the enlargement of the cavity in January, 1954, due to the presence of a check valve, i.e., partial obstruction and the bronchogram revealed a cystlike cavity with a minor degree of ectasis.

Bronchoscopic examination during the disease or clinical cure was carried out in 7 cases. In 3 patients, where cavity was demonstrable radiologically,

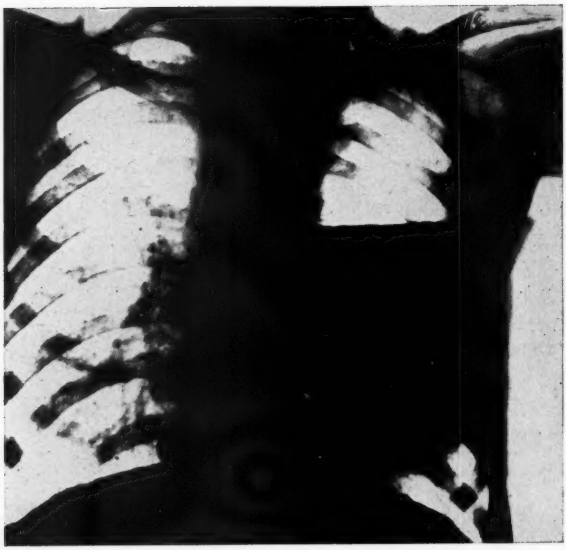

Fig. 8.—A skiagram of the chest (S. K., Dec. 8, 1953), shows a cavity 8 by 6 cm. with surrounding consolidation.

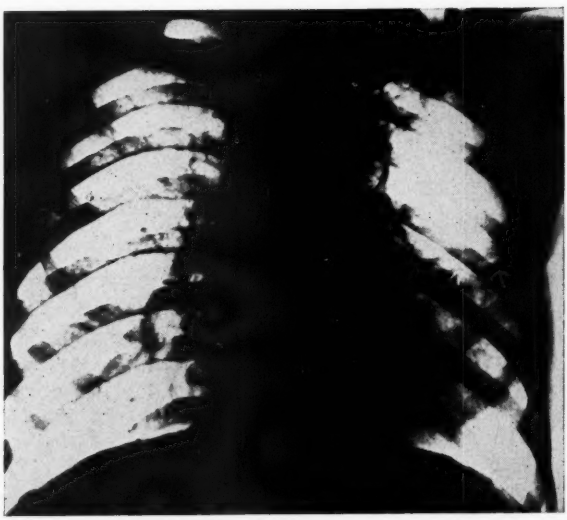

Fig. 9.—A skiagram (S. K., Jan. 2, 1954) showing a cystlike shadow 5.5 by 7 cm.

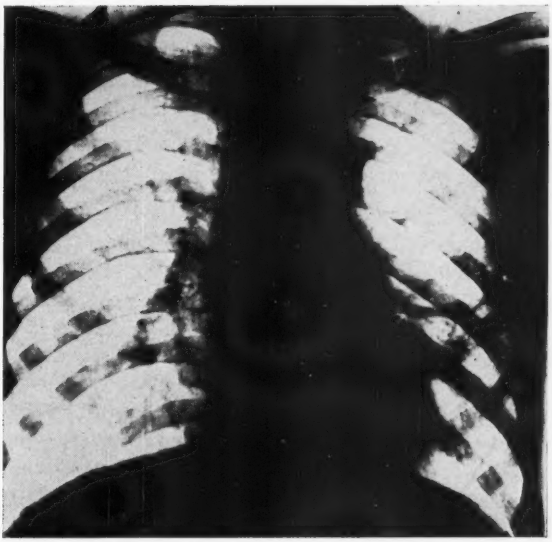

Fig. 10.—A skiagram (S. K., Jan. 16, 1954), showing that the cyst has enlarged to 7.5 by 9 cm. which indicates the presence of check valve phenomenon.

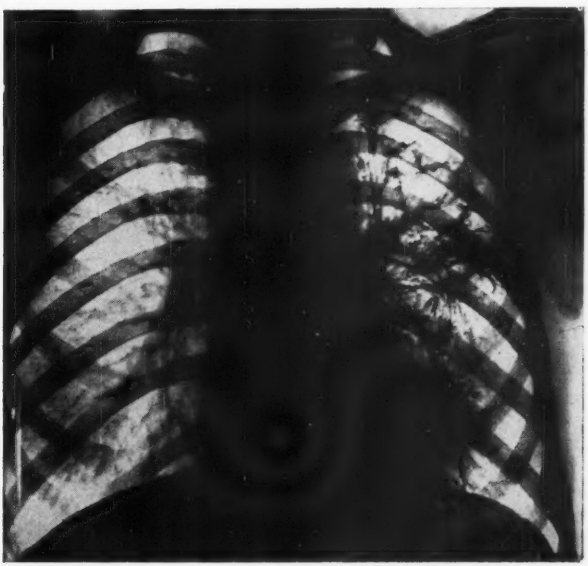

Fig. 11.—A bronchogram (S. K., Feb. 17, 1955) showing a small cystlike cavity with a minor degree of residual bronchiectasis.

the bronchi were full of thick purulent material, the mucosa was inflamed and congested. There was some distortion of the bronchial tree. In 2 patients where there was complete clinical and radiologic cure there was 30 to 50 per cent bronchostenosis with distortion of the bronchial tree. In 2 patients no abnormality was detected.

DISCUSSION

The low incidence of lung abscesses in females in the present study, and also in the reports by Metras and Charpin (1954), Fox and associates (1954), and Gittens and Mihaly (1954), deserves serious consideration. No reasonable explanation is available. Lung abscess secondary to operative procedures has become comparatively much less. In the majority of cases, bronchial embolism takes place during a period when the defensive mechanisms are impaired by the upper or lower respiratory infections. An analysis of the records of this Clinic during the year 1953 revealed certain interesting facts: Of the number of patients suffering from pulmonary tuberculosis, 1,693 were men, and 1,533 were women; of those with other respiratory infections, 2,150 were men, and 808 were women.

Similar observations have been made in deaths accredited to chronic bronchitis by the Registrar General (1946) and Howell (1951), i.e., twice as common in males as compared to females. The incidence of acute pneumonias is 2 to 3 times greater in males than in females. It is difficult to determine whether males are specially susceptible to respiratory infections, or whether it is the occupational hazards, fatigue, and climatic factors which are responsible for this variation in incidence.*

In Brock's (1952) series, the incidence secondary to operative measures was very high. In the present series, however, no case was associated with any operative procedures. Wig (1951) could find only 1 case after tooth extraction in a series of 28 cases. In the present study, only cases where a cavity was seen at either roentgenologic or postmortem examination are included. Basal pneumonia, pneumonitis, or atelectasis is a very common complication of operative procedures. It is difficult to place in a water-tight compartment where a pneumonitis or atelectasis ends and suppuration begins so as to form a definite abscess cavity, as these are the different stages of the same inflammatory process. The appreciation of this postoperative complication and strict prophylactic measures such as frequent change of posture, breathing exercises, and measures not to inhibit the cough reflex must have contributed a great deal to the reduction of the incidence of lung abscess. The situation has further improved a great deal by the administration of penicillin, sulfonamides and other antibiotics as prophylactic measures.

With the meager data at our disposal regarding the bronchoscopic and bronchographic examination in clinically and radiologically cured patients with lung abscess, it appears that segmental bronchi take a prominent part in the suppurative process, and bronchial obstruction, either due to the purulent

*It appears that the incidence of lung abscess runs parallel in females to the incidence of other respiratory infections.

material or the active inflammation of the bronchial mucosa, may lead to certain sequelae such as a minor degree of ectasis or the persistence of cystlike cavities. In interpreting the bronchoscopic findings, the fact that the bronchi cannot be visualized beyond a particular distance must be kept in mind. This ectasis depends on the degree of bronchial obstruction and the inflammatory and suppurative process present in the bronchial tree. It has been shown that simple bronchial obstruction can lead to ectasis due to the retention and dilatation of the bronchi by the mucous. Croxatto and associates (1954), and Medlar (1955) from post-mortem and resected specimens have brought out that if the bronchial pattern is distorted by extensive parenchymal scarring in nontuberculous conditions, the distention of the bronchi distal to the obstruction takes place by either retention of the secretions or the inflammatory products. In about 80 per cent of the cases of lung abscess, there is bronchial embolism followed by segmental atelectasis, finally leading to suppuration. It appears that residual ectasis following abscess depends on the duration of the block (by mucus, purulent material, and the mucosal inflammation and suppuration) and distortion of the bronchial pattern by the parenchymal scarring.

The results are comparable to those of Smith (1948) in his 60 personal cases, Jewitt and Dimond (1950), Metras (1954), Fox and co-workers (1954), and Gittens (1954), i.e., about 60.7 per cent treated with antibiotics. This high cure rate, in comparison with the previous work, is very striking. Smith (1948) in his collection of 1,498 cases from the literature found a cure rate of 10 per cent. Klepser and his colleagues (1952), and Brock (1952) recorded 40.8 per cent as the cure rate. However, Smith (1948) collected the cases from the literature as far back as 1932, when the antibiotics were not known and the only treatment for lung abscess was to drain the pus either by postural drainage, expectorants, or surgical measures.

The results have not been correlated with the duration of the abscess at the time of therapy. Even with the advent of antibiotics and chemotherapeutic agents, the position with regard to chronic abscess has not changed as the antibiotic therapy may sterilize the cavity but does not help to close it. The only remedy for such chronic lung abscess is surgery. In this study, efforts have been made to correlate the prognosis with the duration of the symptoms. It is difficult to place an abscess into an acute or chronic stage as the definition has been changing from time to time. Neuhof (1940) labels abscesses acute within six weeks' duration, subacute from six to twelve weeks, and chronic after twelve weeks. Sweet (1942) extends the period of the acute stage to four months, while Shaw (1942) extends it to six months. Moore's (1942) view seems to be more rational, namely, that chronicity should be judged as revealed by clinical and radiologic study, time element cannot be the deciding factor as the present stage may be the exaggeration of the pre-existing disease. Table IV shows that there were 33 cures (80 per cent) out of 41 patients who were treated within six weeks of the onset of symptoms. While in cases of more than six weeks' duration, there were 8 (40 per cent) cures

out of 19 patients. It is not difficult to foresee that acute abscess of six weeks' duration, if treated with the proper antibiotic in proper doses, may not require any surgical measure.

The dosage schedule in the Group 1 and Group 2 as shown in Table V is very low as compared to the present-day conceptions. It is possible that if high doses of penicillin, namely, 10 lacs twice a day, are given in every case the cure rate may increase further.

The broad spectrum antibiotics should be tried in selected cases where the organisms are highly sensitive to Aureomycin, Terramycin, Achromycin or Ilotycin. In the present study, as already stated, all the 6 patients submitted to Aureomycin showed remarkable clinical and roentgenologic healing. Chandler and co-workers (1949) reported a patient with multiple lung abscess which responded to Aureomycin, while penicillin, sulfonamides, and streptomycin did not alter the course. Gruber and associates (1950), too, described a case of an infant with multiple cavities which showed an impressive response under a combination of streptomycin and Aureomycin with sterilization of the sputum and closure of the cavities. Gittens and Mihaly (1954) have also reported good results in acute lung abscesses treated with the tetracycline group of drugs. Barach and his colleagues (1952) in an excellent review are of the opinion that chronic pulmonary suppuration does not respond in a striking manner to Aureomycin.

It appears from the present study that in abscesses of recent origin a fair trial of antibiotics should be given and about 80 per cent of such abscesses will completely heal, clinically and radiologically. There is little disagreement with Brock's (1952) view that the expectant line of treatment should be continued so long as there is clinical and roentgenologic improvement. Large doses of penicillin and the tetracycline group of drugs should be tried in resistant cases.

SUMMARY

A study of 60 cases of lung abscess is presented. No case secondary to operative procedure was found. It appears that prophylactic use of antibiotics and other measures have reduced the incidence. The low incidence of lung abscess in females is a very remarkable feature. Perhaps it runs parallel to the low incidence of other respiratory infections like bronchitis and pneumonia in females. The residual bronchiectasis is usually symptomless and is due to the active part played by the bronchi in the pathologic process. With the use of antibiotics in large doses in acute lung abscess, a cure rate of about 80 per cent can be achieved.

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ERYTHROMYCIN AS PROPHYLAXIS IN PULMONARY RESECTION

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PARENTERAL use of various drugs as prophylactic agents against postsurgical infections has been practiced since effective chemotherapeutic agents became available.[1, 2] Because empyema constitutes one of the more serious complications after pulmonary resection, often resulting in a high mortality rate or prolonged course of hospitalization for the patient, there is a continuing necessity to seek a more effective prophylactic agent. In recent years, antibiotics have become decreasingly effective in preventing this complication due to increasing bacterial resistance to the drugs. This has been evident especially in the case of penicillin-resistant staphylococci.[3] Also, there is no certainty that the various drugs are distributed in adequate concentration after parenteral administration in the pleural space especially in cases of this type where need for the drug is greatest. This is true particularly with penicillin on which detailed studies have been made.[4]

With the discovery of erythromycin,† the problem of penicillin-resistant bacteria has become easier to manage because of the drug's high activity against the microorganisms[5-7] most often implicated in empyema. Furthermore, the lack of toxicity and the demonstrated accumulation of the drug when given in multiple intrapleural[8, 9] doses make this antibiotic a practical one to use as a prophylactic agent in thoracic surgery. Thus, the purpose of this investigation is to determine if erythromycin would provide adequate antibiotic coverage in patients undergoing pulmonary resection.

MATERIALS AND METHODS

Thirty patients undergoing lung resection in this institution served as subjects for this study. All antibiotics were discontinued three days prior to the start of the experiments and only erythromycin was administered postoperatively. This series of patients was divided into two groups depending on the absence or presence of intrapleural catheter drainage after surgery, namely,

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†Erythromycin used was supplied by Abbott Laboratories, North Chicago, Ill.

pneumonectomy and partial resection cases, respectively. In the pneumonectomy group, there were 18 patients, 12 of whom were studied after receiving a single injection of erythromycin; of these 12, 8 patients had received 250 mg. and 4 had received 400 mg. of erythromycin. Patients in this group were given the drug intrapleurally immediately after closure of the chest, through the needle used for measurement of intrapleural pressure. In all cases, the drug administered intrapleurally was the lactobionate salt of erythromycin in 1 per cent solution. The remaining 6 patients in this group were given an initial instillation, with subsequent injections made by the barbotage method in order to avoid painful intrapleural reaction.[9] To 12 patients, who comprised the partial resection group, 250 mg. of erythromycin was given after closure of the chest through the anterior catheter inserted at the level of the second anterior interspace while a second catheter, inserted in the posterior axillary line at the level of the eighth or ninth interspace, was clamped off. Then the anterior catheter was clamped and the patient transferred to his room where flasks were connected to the catheters between the patient and the water-seal bottles. The clamps were then removed and serosanguineous intrapleural fluid draining through the catheters was trapped in the flasks. On subsequent days, the administration of erythromycin was continued by the oral or intravenous route.

Blood samples were taken from the patients of the pneumonectomy group at 30 minutes, 1, 2, 3, 4, 6, 12, 15, 24, 36, and 48 hours after the 400 mg. dose. From the patients given the 250 mg. dose, blood specimens were taken at 1, 3, 4, 8, 12, 24, 36, and 48 hours. Serosanguineous intrapleural fluid samples were drawn at 24, 36, and 48 hours after injection of both doses of erythromycin. Twelve-hour urine specimens, obtained by catheter left in situ, were collected for the 48-hour period of observation. From those given multiple doses of the drug, similar blood samples were taken each day; intrapleural fluid was taken at the end of each 24-hour period just prior to the injection of the next dose. Daily total urine specimens were also collected.

In the partial resection cases, blood samples were drawn hourly from the patients for the first 6 hours and at the ninth and twenty-fourth hours after injection. Total intrapleural fluid was collected hourly for the first 6 hours, followed by collection of the fluid in each 6-hour interval for the 24-hour period. Urine specimens for 3-hour intervals were collected via a urethral catheter during the first 12-hour period followed by a total 12-hour specimen.

Drug concentration was determined on all specimens collected. The volume of intrapleural serosanguineous fluid trapped in the flasks from partial resection patients and all urine samples were measured and the total amounts of erythromycin present in the samples were calculated. The method used to determine drug concentration was that of Loo and associates,[10] employing the paper-disc agar diffusion technique. Intrapleural fluids were examined microscopically and cultured for the presence of any microorganisms. The patients were observed closely for two weeks in the immediate postoperative

period. Particular attention was paid to temperature, and pulse and respiration rates, as well as to any signs of toxic or septic condition of the patients during this period.

RESULTS

A. Intrapleural Fluid and Serum Levels and Urinary Drug Excretion

1. Pneumonectomy Cases.—The graph in Fig. 1 shows the average values of intrapleural fluid and serum levels and urinary drug excretion in patients given a single dose of 250 or 400 mg. At 24 hours, the respective intrapleural fluid levels were 12.2 and 26.5 mcg./ml. declining to 10.1 and 19.8 mcg./ml. at 36 hours, while at 48 hours the respective levels were 4.5 and 6.8 mcg./ml.

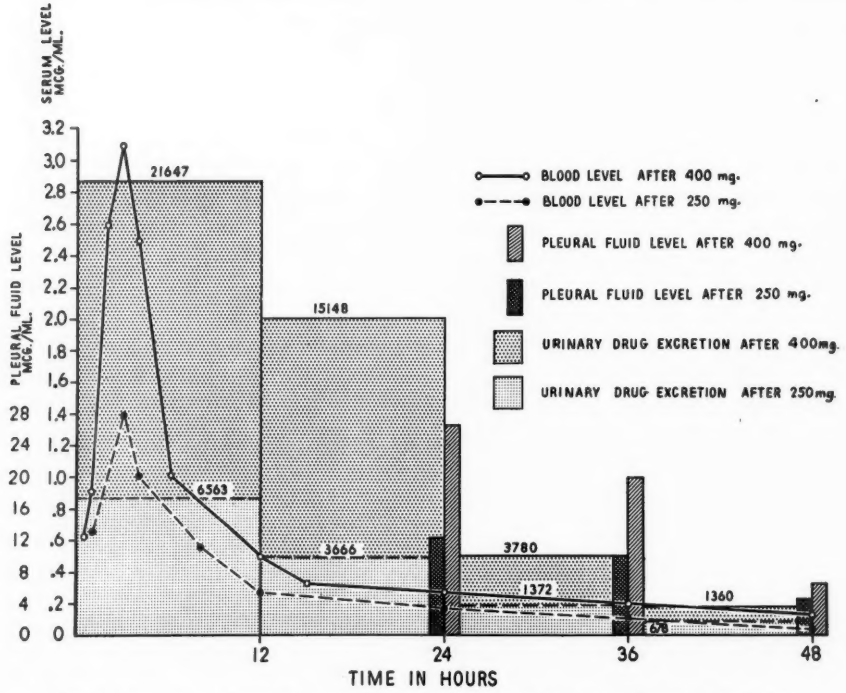

Fig. 1.—Effects on serum of single intrapleural doses of 250 and 400 mg. of erythromycin, intrapleural fluid concentrations, and urinary drug excretion in pneumonectomy patients. Average results from the use of 250 mg. on 8 patients, and 400 mg. on 4 patients.

Figs. 1 and 2 taken from M. López-Belio and Y. Takimura, Intrapleural, Intravenous and Oral Administration of Erythromycin. Comparative Studies of Serum and Pleural Fluid Levels and Urinary Drug Excretion, Antibiotics Annual 1954-1955, Medical Encyclopedia, Inc., New York. Permission granted by Henry Welch, Ph.D., editor.

These concentrations of erythromycin are inhibitory to all susceptible microorganisms. Serum levels followed the same curve as the intrapleural fluid levels, reaching a peak concentration at 3 hours of 1.4 mcg./ml. with a 250 mg. dose and 3.1 mcg./ml. with the 400 mg. dose. Thereafter, there was a gradual decline in the levels until at 24 hours the concentrations were 0.16 and 0.27 mcg./ml., respectively; 48-hour levels were 0.04 and 0.12 mcg./ml.

Total drug excretion in urine in general followed the curve of the serum levels. The total 48-hour drug output in urine was 4.8 per cent of the 250 mg., and 10.5 per cent of the 400 mg. dose administered. During the first 12-hour period with the 250 mg. dose, drug excretion amounted to 52.7 per cent of the total in 48 hours; in each of the subsequent 12-hour periods 30.3 per cent, 11.4 per cent and 5.6 per cent, respectively, of the 48-hour drug excretion were found. Similarly, with the 400 mg. dose, the corresponding figures were 51.6 per cent, 36.1 per cent, 9.0 per cent, and 3.2 per cent.

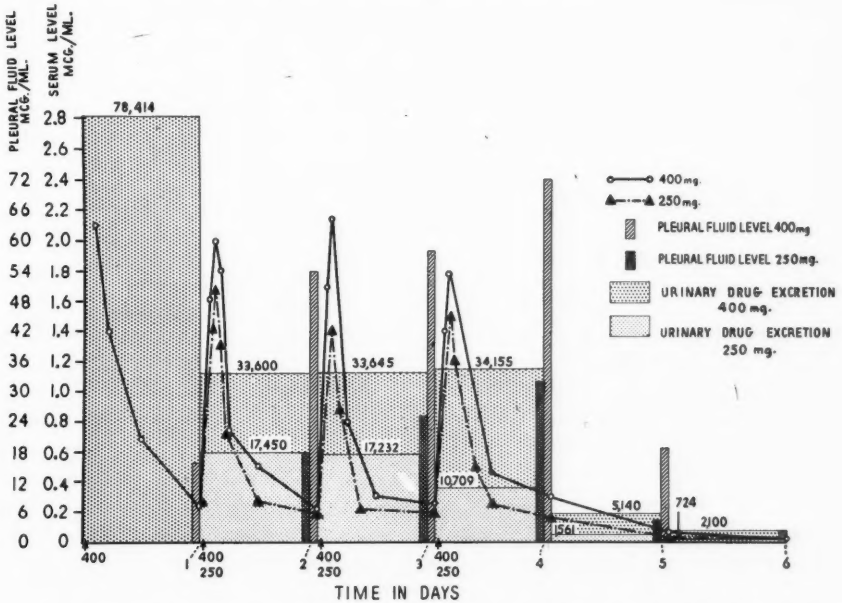

Fig. 2.—Effects on serum of multiple intrapleural doses of erythromycin, intrapleural fluid concentrations, and drug excretion in the urine of pneumonectomy patients. Average results from 3 patients who were given initial 400 mg. doses followed by daily instillations of 250 mg., and from another group of 3 patients, given 400 mg. daily for 3 days, after the initial dose of 400 mg.

The effect of multiple doses of erythromycin on serum levels was similar to those seen with the single dose. However, determinations of the drug concentration in intrapleural fluid withdrawn just prior to the daily injection revealed a rising level, increasing from 15.5 mcg./ml., 24 hours after the first injection of 400 mg., to 31.6 and 72 mcg./ml., 24 hours after the last injection of 250 and 400 mg., respectively. Thereafter there was a rapid decline in the levels which, however, were of effective concentration 48 hours after the last injection of 250 mg. and 72 hours after the last 400 mg. dose. Daily urinary drug excretion after the first day remained approximately at a constant level during administration. Average daily drug excretion during administration amounted to 6.1 per cent of 250 mg., and 8.5 per cent of the 400 mg. dose. These results are seen in the graph of Fig. 2.

2. Partial Resection Cases.—The average loss of erythromycin through the intrapleural catheters as well as by excretion in urine, and concentration in blood serum during the 24-hour period in this group of patients after intrapleural administration of 250 mg., is shown graphically in Fig. 3. The total amount of the antibiotic lost in 24 hours through the catheters was 130.11 mg. which is 52.2 per cent of the dose given. In the first hour, 43.5 per cent of the dose was found in the drainage fluid; from the second to the sixth hour,

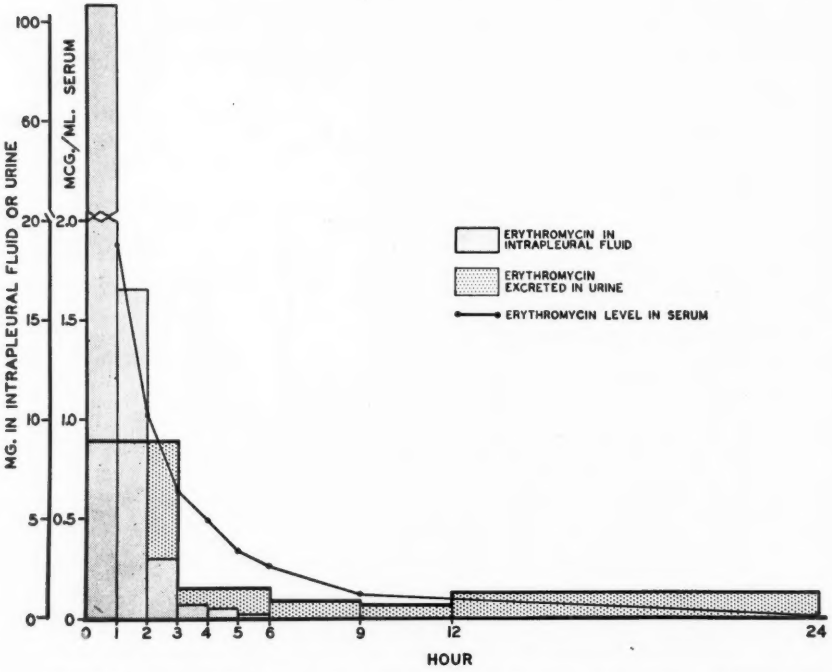

Fig. 3.—Erythromycin serum concentrations, loss through intrapleural catheter, and excretion in urine, after the intrapleural instillation of 250 mg. of erythromycin through the intrapleural catheter as the chest was closed after partial lung resection. Average results from 5 such patients.

8.5 per cent was eliminated and only 0.12 per cent was found in the last 18 of the 24-hour period. Total urinary excretion of erythromycin for 24 hours was 5.3 per cent of the dose, or 13.15 mg. In the first 3 hours, 3.5 per cent was excreted, while in 6 hours 4.1 per cent was eliminated; thus 1.2 per cent was found in urine in the last 18 hours. The total loss of erythromycin, therefore, was 57.5 per cent in 24 hours, 55 per cent of the dose being accounted for during the first 3 hours. Concentration of the drug in serum was high after 1 hour, the level being 1.88 mcg./ml. but declined rapidly in keeping with the large amounts lost through the catheters and in urine; however, inhibitory concentration of erythromycin against staphylococci was found in blood at 12 hours.

B. Clinical Observations

In the group of 18 pneumonectomy patients, during administration of erythromycin, intrapleural serosanguineous fluid was withdrawn daily after surgery. The fluid showed no change in color or consistency and no evidence of bacterial growth was noted with either the 250 or 400 mg. dose given. The postoperative course of these patients was uneventful; temperature returned to normal in 24 to 36 hours, and blood pressure, pulse and respiration rates were all within normal limits. Soft tissue infection failed to develop and postoperative infection of the pleura or lung parenchyma was absent in all patients. One of these patients, however, died on the eighth postoperative day. Death resulted from pulmonary edema due to left heart failure which was confirmed by post-mortem findings. The patient had received the last dose of 250 mg. 48 hours prior to death; immediately after death, cardiac puncture and pleural aspiration were performed. The specimens appeared to be grossly normal. Bacteriologic examination was negative and erythromycin concentrations were 0.04 mcg./ml. in heart blood, and 3.0 mcg./ml. in pleural fluid.

The 12 patients who comprised the partial resection group and were given 250 mg. in single dose and continued on oral or intravenous administration after the first day, also had an uneventful postoperative course similar to the pneumonectomy patients. In all of these patients with intrapleural catheters, infection at the site of insertion of the catheters did not develop. After removal of the tubes the orifices healed by first intention. Postoperative complications, due to infection by pyogenic microorganisms, were absent. One exception was noted in a patient who had had a double segmentectomy (the apicoposterior segment of the upper lobe and the superior segment of the lower lobe) of the left lung. This patient was given erythromycin intrapleurally at the time the chest was closed and later maintained on an oral dosage, when, on the fifth day a bronchopleural fistula with concomitant pyogenic empyema was discovered. General toxic signs were evident and the patient was then placed on 5 days of intensive erythromycin therapy given by continuous intravenous drip. A rapid and remarkable response was noted. Cultures of specimens obtained from the catheter, previously positive for *Micrococcus pyogenes* var. *aureus,* became negative. Subsequently, with continued improvement on oral medication, a thoracoplasty was performed and the patient recovered completely.

DISCUSSION

The effect of intrapleural administration of erythromycin on serum levels appears to be dependent on the type of resection undergone by the patient. The difference is due largely to the presence of the intrapleural catheter as found in partial resection cases or its absence, as in pneumonectomy. In the latter group, there is a build-up of serum levels which reached peak concentration at 3 hours but in the former group the serum levels showed immediate decline from the initial peak value at 1 hour. With a comparable dose, the 3-hour level was approximately one half in the partial resection group compared to that of the pneumonectomy group; coincidentally the former group

showed, in the first 3 hours, a loss through the catheters of 51.5 per cent of the drug given. Another difference between the two, which may influence serum levels, is that in the pneumonectomy patient there is a limited pleural area for absorption, whereas in the other patients the pleural surface is more extensive, permitting a more rapid absorption of the drug from the pleural space. Thus, comparison of the 1-hour levels shows that partial resection patients had considerably higher levels than the corresponding ones who had had a pneumonectomy. After these differences, the serum concentration curves show a similar pattern. However, the continued loss of erythromycin through the catheters in the partial resection patients resulted in a shorter period of effective levels; the 12-hour level in these patients corresponding to the 36-hour level in pneumonectomy patients. In pneumonectomy cases, the administration of a larger dose affected serum levels in the expected manner. The 400 mg. dose compared to that of 250 mg. resulted in elevated serum levels and a more prolonged effective concentration. The pleural fluid levels showed similar effects, with the larger dose resulting in higher levels. Hence, more than adequate coverage against susceptible pyogenic bacteria by erythromycin was present in pneumonectomy patients and, to a lesser extent, for a shorter period of time, in the partial resection patients.

Prior to the availability of penicillin, empyema was the most frequent complication following pulmonary resections. However, results with the use of antibiotics as prophylactic agents, particularly penicillin, do not indicate uniform effectiveness of this antibiotic for this purpose in lung resections. Of the 21 resections for suppurative disease of the lung reported by White and his colleagues,[11] 12 patients given penicillin did not develop empyema while all 9 patients in the control group had this complication. On the other hand, of Blades' series[12] of 59 similar cases, 11 of the 29 patients given penicillin developed empyema as well as 12 of the 30 patients without this antibiotic. Neither of these reports shows data indicating the development of empyema as a consequence of bronchopleural fistula. At this institution,[13] of the 25 tuberculous patients undergoing pulmonary resection without antibiotic coverage, 10 had nontuberculous empyema; 4 of the primary type, and 6 secondary to fistula. In contrast to this unprotected series, penicillin given irregularly by the intramuscular or intrapleural route in 21 patients was followed by 2 cases of primary pyogenic empyema and 3 cases secondary to fistula. Subsequent to the 21 cases, a review of 274 consecutive pulmonary resections with penicillin and streptomycin revealed 16 cases of nontuberculous empyema occurring before the tenth postoperative day, 11 resulting from the development of bronchopleural fistula. Therefore, even with antibiotic protection, the presence of a bronchopleural fistula favors the development of an empyema. This was seen in the present study in the one patient whose empyema was secondary to the development of fistula and in whom the prophylactic effect of erythromycin was not evident. Even in this case, erythromycin appeared to be of value in controlling the infection, but it should be noted that its effectiveness was due to the higher drug concentration attained by intravenous infusion and not by oral administration, although the latter

route was sufficient to prevent infection in patients without a bronchopleural fistula. Thus, the intrapleural dose in the partial resection cases should be augmented, generally in 12 hours, by oral or intravenous administration; the intravenous route is indicated especially when the likelihood of infection is present. It is felt that this is a particularly important point to consider since tissue concentration of the drug may be related directly to the serum concentration and that the latter, although relatively unimportant in itself, is a measure of the drug concentration at the focus of infection.[14, 15] Indeed, it is known that with penicillin the diffusion from the blood stream into the pleural space is inadequate.[16, 17] However, we have found erythromycin to have considerably greater diffusibility.

In most of the above reports, there is little or no information on the resistance or sensitivity of the microorganisms to penicillin, although this information is vital in the evaluation of the effectiveness of this drug. Further information required for the adequate evaluation of any prophylactic agent in pulmonary resection should concern the type of resection undergone by the patient. As mentioned previously, there is a difference in drug concentration in serum and in intrapleural fluid, depending upon the type of resection performed, but aside from this consideration is the fact that pneumonectomy patients with a complicating fistula invariably develop empyema whereas in partial resection patients development of a fistula does not necessarily result in empyema.

SUMMARY AND CONCLUSION

Erythromycin was found to be an effective prophylactic agent against pyogenic empyema in pulmonary resection cases except in cases in which empyema was secondary to the development of a bronchopleural fistula. The effectiveness was dependent on the type of resection; specifically, the presence or absence of intrapleural catheters was the major factor. In the pneumonectomy group, effective concentration of the drug was found 48 hours after a 250 mg. intrapleural dose, and 72 hours after a dose of 400 mg., intrapleurally. The partial resection cases, however, had a more limited period of effective antibiotic coverage because approximately 50 per cent of the drug was lost through the intrapleural catheters, during the first 3 hours. Thus, in the latter type of case, the intrapleural dose should be augmented by oral or intravenous administration, depending on the condition of the patient. In patients without bronchopleural fistula, erythromycin was felt to be effective in preventing the development of empyema; but even in those cases of fistula and concomitant empyema, the drug is felt to be of value in bringing about a marked improvement in the general condition of the patients so that a further surgical procedure becomes feasible at an earlier time. The important factors necessary for the proper evaluation of antibiotics as prophylactic agents in pulmonary resection are considered to be the presence or absence of bronchopleural fistula, adequate local concentration of the drug, and sensitivity or resistance of the particular microorganisms to the antibiotic under study. The role and importance of bronchopleural fistula in the development of empyema are discussed.

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Announcements

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

The Thirty-seventh Annual Meeting of The American Association for Thoracic Surgery will be held May 4, 6, and 7, 1957, in Chicago, Illinois. Headquarters will be at the Palmer House.

Requests for Hotel Reservations

These should be mailed directly to Mr. Edward Langford, Reservations Manager, Palmer House, Chicago. Please mention this Association, the type of accommodation desired, the date, and approximate hour of arrival and departure. If accommodations are desired elsewhere in Chicago, please communicate directly with the hotel of your choice.

Thoracic Surgery Forum

The Thoracic Surgery Forum will be continued as a special session at the 1957 meeting. The Forum is primarily for the presentation of short papers on current thoracic research, experimental problems, anatomical studies, and modified or new surgical techniques. The inclusion of any considerable amount of clinical material in these reports makes the choice more difficult and the Program Committee reserves the right to reject such papers, or to suggest their transferal to the Regular Program.

Papers at this session will be limited to ten minutes, including the showing of lantern slides or other illustrative material. At the discretion of the President, three minutes may be allowed as the maximum discussion for each paper.

All Thoracic Surgery Forum papers will be published together in one issue of the JOURNAL. Maximum length: 3000 words without illustrations. If illustrated, an appropriate number of words must be subtracted for each cut used.

Abstracts of Papers

Abstracts of all papers for presentation at the 1957 meeting must be received on or before Dec. 15, 1956, otherwise they will not be considered by the Program Committee.

Abstracts should be labeled "For Thoracic Surgery Forum," or "For Regular Program." The abstracts should contain from 200 to 250 words and accurately reflect the contents of the completed paper.

Five, repeat, five copies of *each* abstract must be sent to Miss Ada Hanvey, Administrative Assistant, The American Association for Thoracic Surgery, 600 South Kingshighway, St. Louis 10, Missouri.

Those on the program are reminded that papers presented at the meeting *must* be handed to the secretary immediately after their presentation. If they are not ready at that time there is a chance that they will not be published in THE JOURNAL OF THORACIC SURGERY.

Motion Picture Session

Provisions have been made to show a limited number of motion pictures to be selected on a competitive basis. *The films themselves,* together with descriptive material concerning length of presentation, etc., must be received by Dr. Karl P. Klassen, The Ohio State University, Columbus 10, Ohio, before Dec. 15, 1956.

It is planned to run the motion pictures in a smaller room at the same time as the scientific sessions. If the films are well labeled, it will not be necessary for the author to be present for comment.

Applications for Membership

Applications for Associate Membership in the Association must be received by the Membership Committee not later than Dec. 15, 1956, otherwise the application will be deferred for consideration until the 1958 meeting.

Applicants must be sponsored by three Active or Senior Members of the Association. In addition to the signatures on the application form, the sponsors will forward a *separate* letter concerning the applicant directly to:

Dr. O. T. Clagett
Chairman of the Membership Committee
Mayo Clinic
Rochester, Minn.

Sponsors are reminded that *new* letters of recommendation must be forwarded to the Membership Committee should their applicants be held over for reconsideration a second year. The new letters of recommendation should also be sent to Dr. Clagett, the Chairman of the Membership Committee.